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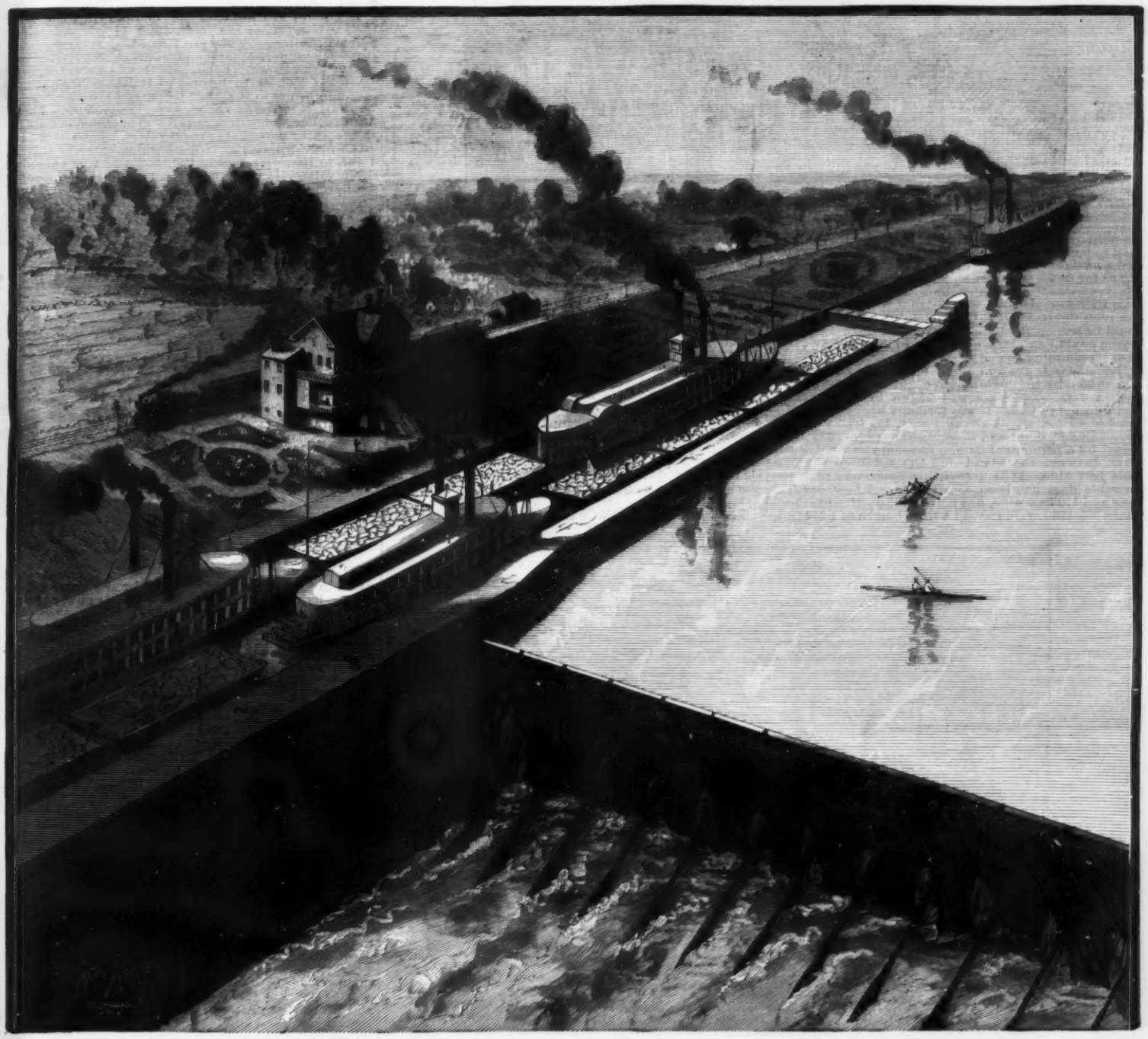
THE DAVIS ISLAND DAM ON THE OHIO RIVER, PITTSBURG, PA.

AFTER over five years of use, Davis Island dam has proved itself a success far beyond expectation. It not only assures Pittsburg a splendid harbor during the dry summer months, but has facilitated river transportation from Pittsburg so that more than double the amount of traffic can be accommodated on a "rise" now than could be before the completion of the dam. Last June, however, its practicability was shown more than ever before, owing to a combination of circumstances. Prior to the completion of the dam, which is a movable one, and can be lowered flat on the bottom of the river in case of high water or ice, Pittsburg had a very poor harbor. Coal is the great article of river commerce from Pittsburg. Formerly, very little could be safely moored at the city. All the coal loaded into coal boats and barges (crafts which draw about 6 to 8 ft. of water), therefore, had to be harbored in the Monongahela River, which is a slack water stream. Boating can be done on the Monongahela even in times of lowest water, but on the Ohio only in times of "rises" or freshets. Consequently, whenever there was a "rise" there would be a great rush at the locks of the Monongahela River to get the loaded coal down to Pittsburg to make up tows for the large tow boats at Pittsburg to take down the Ohio. Often the water would fall before a very great amount of coal could be locked through the locks and the big tow boats could get started from Pittsburg, and the trip would have to be abandoned.

Now, all the coal loaded on the Monongahela is towed immediately to Pittsburg, because Davis Island dam makes an excellent harbor for the city. Fully 20,000,000 bushels can be harbored safely. Whenever a rise occurs now, all the big tow boats have to do is to make up their immense tows and start down the Ohio. The dam is lowered every time there is a rise, and the boats have not the trouble and delay of passing through any locks. During the month ending July 11, three rises occurred, on which nearly 30,000,000 bushels (over 1,000,000 tons) of coal were taken to the markets in the South and Southwest. On June 8 and 9 over 16,000,000 bushels of coal were towed away from Pittsburg. A few years ago such immense shipments would have been impossible, but Davis Island dam has made them not only possible, but practicable and safe. Notwithstanding the great distance from most of its markets, the excessive rates of toll charged by the navigation company on the Monongahela, and the extensive use of natural gas, the Pittsburg coal business is increasing rapidly, and Davis Island dam is largely the cause of it.



THE MOVABLE DAM ON THE OHIO RIVER, AT DAVIS ISLAND, PITTSBURG, PA.

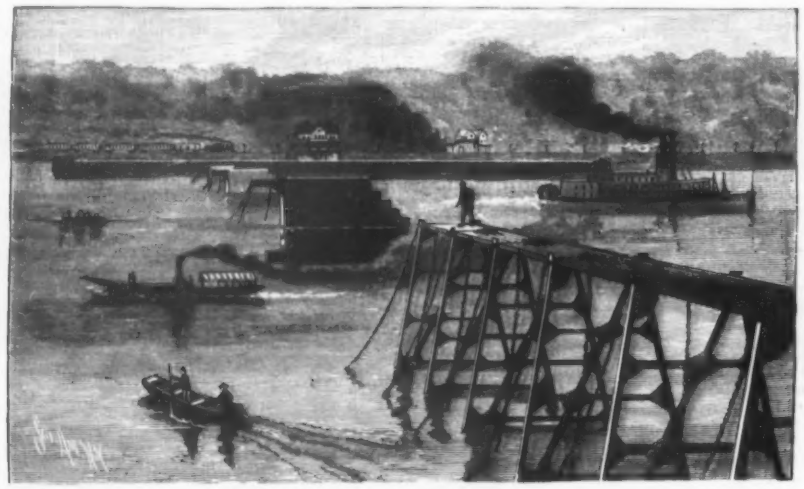
In the olden days, when Fort Duquesne was on the extreme colonial frontier, the restless waters of its two encircling rivers met below the old fort to form the broad Ohio, and together flowed toward the sea in unrestrained freedom. In winter and spring mighty torrents rushed hurriedly past the fort and onward to the great valley. In summer and autumn, when heat and drought had quenched the tributary fountains, these torrents were replaced by broad, shallow streams, scarcely navigable for heavier craft than the frail canoes that formed their only fleet. But when the old fort had grown into a famous trading post, and then into a brisk city, this intermittent navigation became extremely disadvantageous. The large mineral resources of Western Pennsylvania were being developed, and their product of coal and iron distributed throughout the South and West by means of the natural waterways afforded by the Ohio and Mississippi.

Pittsburg's commerce had stretched out its hands until her steamers had gone into the Northwest as far as the Upper Missouri, a distance of 4,300 miles, and on the South as far as New Orleans and the Gulf. Each year the traffic grows larger, until at the present time the tonnage of the port of Pittsburg exceeds that of New York.

Its growing requirements strongly demand improved

facilities of water communication. The Monongahela has already been made navigable for many miles above the city by an elaborate system of fixed dams and locks. The Allegheny remains for the most part unimproved. Penetrating as these rivers do to the North and South, they bring a large region of rich and productive country into communication with the city at their mouths, and further improvements to navigation will extend the area of the tributary district. But the actual port of the city has not until recently been free from the interruptions caused by the low water of summer.

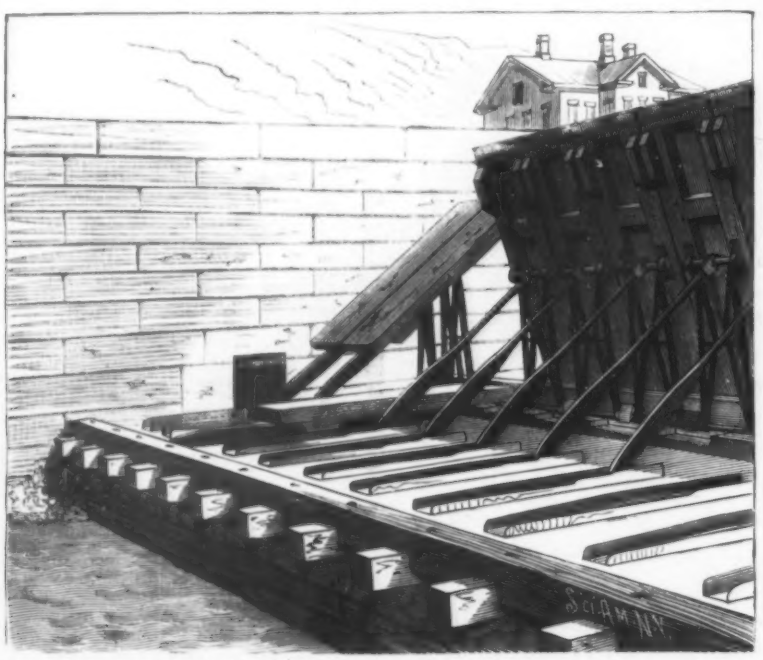
The only practicable way of improving it lay in damming the Ohio, and so raising the water level. But it would have been a manifest disadvantage to turn this immense tonnage through a lock all the year round in order to make the traffic continuous from one



SERVICE BRIDGE AND PIERS.

ice-bound season to the next. The two conditions necessary to be considered—an open passage at high water and a navigable pool surrounding the city and extending as far down the river as possible, at all seasons of the year—made a movable dam highly desirable. It was, therefore, decided to construct a wicket dam, on the plan devised by M. Chanoine, by which the river could be left open at high water, and during the dry season could be so far confined as to make a navigable pool surrounding the city.

Davis Island, five and a half miles below Pittsburg, was chosen by the government engineers as the site for such a dam. The work was begun in August, 1878, and finished in 1885. It was formally opened on October 7 of that year. A channel way, 456 feet wide, between Davis Island and the southern shore has been closed by a permanent dam. The main channel of the river, between the island and the northern shore, is 1,344 feet wide. It is across this water way that the movable dam has been constructed. A lock, 689 feet long and 110 feet wide, has been built on the northern shore. A land wall, having a total length of 1,649 feet,



VIEW FROM BELOW, SHOWING THE WICKETS IN DIFFERENT POSITIONS.

extends along the bank. A wall of solid masonry, 19½ ft. high, 11 ft. wide at its base, and 8 ft. on top, separates the lock from the river.

Between the wall and the island the channel is divided into the Pass, 559 ft. wide, and three weirs of 224, 224, and 216 ft. respectively. The weirs are separated from each other and from the ship channel—the Pass—by masonry piers. The dam consists of a series of 305 movable wickets, which lie flat on the river bed during high water, and are only raised into position when the river has fallen so low as to make navigation difficult or impossible.

The wicket consists three parts, the wicket proper, the horse, and the prop. The wickets are made of white oak, and are 3 ft. 9 in. wide. Their length varies from 12 ft. 11 in. in the Pass to 9 ft. 9 in. in the weir nearest the island. They are placed 4 ft. between centers, thus leaving a space of 3 in. between them, through which the overflow water passes. When the river is too low to permit this waste, pieces of scantling are put down over the openings, the weight of water being sufficient to hold them in place. The wicket is journaled to the horse at a point just a little above its center. The lower part of the wicket is weighted in order to keep it down. The horse is a frame of wrought iron, 6 ft. 8 in. long, which is journaled in a cast iron box in the bottom of the river. These horse boxes are fastened to stout timbers on the river bed, which in turn are secured by iron rods, 9 ft. long, to a buried timber which serves as an anchor.

The prop is journaled to the crosshead of the horse, its free end being supported, when the dam is up, by means of the Pasqueau "hurter." This ingenious device is a cast iron box, 9 ft. long and open at both ends, which rests upon the bottom of the river. When the wicket is raised into position, the end of the prop slides along the bottom of the box, and up a slight inclined plane occupying one-half the width of the bottom, until it reaches the end of the plane and drops down into a notch, where it is held by the pressure of the water against the wicket.

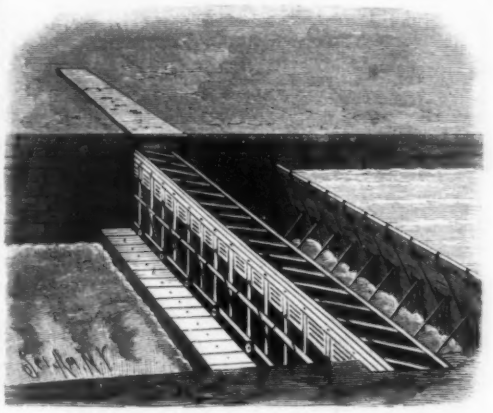
When the wicket is to be lowered, it is pulled forward slightly until the prop is disengaged from the notch and falls to the bottom of the hurter. As the wicket is lowered, the end of the prop, guided by a beveled edge, slides to one side of the inclined plane, and so along the bottom of the hurter until prop, horse, and wicket are flat on the bed of the river. The Pasqueau hurter, like the entire system of wicket dams, is a French invention. Its characteristic feature, upon which the Pasqueau patent was taken out, is the beveled edge, by which the end of the prop is guided to one side of the inclined plane, and permits the wicket to be lowered.

The wickets across the navigable pass are operated from a "maneuvering boat." In closing the dams a hook is inserted in the lower end of the wicket. This is then drawn forward until the prop falls into the notch in the hurter, the wicket proper remaining all the time like a feathered oar, with its broad side parallel to the current. When the prop is securely in place, the lower end of the wicket is gradually allowed to sink until it rests against a sill in the bottom of the river. The wicket must be held by the hook until it rests against the sill, otherwise the force of the current would soon prove destructive. When the dam is to be lowered, a hook is inserted into the upper end of the wicket, and by means of a windlass on board the boat, is drawn in until the prop is disengaged, and allows the whole affair to sink to the bottom. Both in raising and lowering the dam each wicket is operated separately.

The system of wickets in the weirs is precisely similar to that in the pass and across the head of the lock, but it is operated from a "service" bridge in place of the boat. This bridge is a light iron structure, some feet above the dam, and when not in use collapses at right angles to the current. It is built in sections, as shown in our illustration, and stands 15 ft. 1¾ in. above the river bed. The supports are 8 ft. apart, and are hinged at their lower ends to suitable sills. A section of flooring sufficient to span the intervening space is hinged to each support, and goes down with it. A chain connects the free end of the flooring section with the adjoining support nearest the island. When collapsed, the sections lie flat on the river bed, overlapping each other, after the manner of a fallen row of bricks. When the bridge is to be erected the section nearest Davis Island is first put in place, and by means of the chain connection, the succeeding ones are one by one brought into position. The supports projecting from the upper side of the piers are in the line of the bridge, and divide it into three larger sections, corresponding to the weirs.

The lock, in addition to several novel features of construction, possesses an interest as being the largest, both in length and breadth, in the world. A dam of 27 wickets extends across its upper end. This is only brought into requisition when the lock is first used or taken out of use. It is for the purpose of giving slack water in the locks, as it would be impossible otherwise to operate the gates. While the lock is in use the weir will be unnecessary, as the water will always be slack, either the upper or lower gate being at all times closed.

The gates are alike, except in the arrangement of their valves. They are 14 ft. high, 13 ft. 7⅞ in. wide, and 118 feet long. They are formed of several Howe trusses laid horizontally and connected by a heavy timber framework. Each gate runs on a track, and when the lock is to be opened is drawn into a corresponding recess in the river bank. In the lower gate there are 14 butterfly valves, 38 in. in diameter. These are all connected with one shaft and operated in unison. In the upper gate there are no valves. Each shore recess is provided with seven discharging butterfly valves, 4½ ft. in diameter, and in the river wall there are also seven valves, 4½ ft. in diameter, making the filling and discharging area of the valves the same. A turbine



UPPER GATE AND SHORE RECESS.

wheel in the river wall is operated by the water entering the lock through these valves, and its power is utilized to pump water into two tanks on the bank, which have a total capacity of 79,000 gallons. When full, these tanks give a fall of 64 ft., and serve to operate a turbine at each gate.

In this manner all power required by the lock is furnished by the river. The turbine at the upper gate is smaller, because less power is required to move the gate. Being so largely of timber, the gate will almost float; and being at the same time so nearly submerged, it has little weight, and requires therefore but little power to operate it. The lower gate, however, is different. It moves almost entirely out of the water, and requires a larger turbine for its operation.

The work of building the Davis Island dam has been subject to a great many interruptions and delays. It has cost the government about nine hundred thousand dollars. It is presumed that the annual maintenance will be about six thousand.

When the dam is up, it gives back water on the Monongahela to Dam No. 1, a distance of 6½ miles, and on the Allegheny to 36th Street, a distance of 7 miles. This makes a depth of 12 ft. at the dam and about 6 ft. at Pittsburg, giving a pool, therefore, which is navigable in the driest seasons. The dam will only be used for a few months during the summer. Some idea of the enormous tows that pass down the Ohio at this point can be gained from considering a single instance, where 22,000 tons of coal were carried at one time to the markets further down the river. Such a cargo is greater than the famous Great Eastern ever handled, and it is worthy of note that the expense of transportation is lower than in any other system of carriage on record. The coal barges carry about 500 tons each, and the boats about 760 tons. Lashed together, three abreast, and lying low in the water, they look at some distance like immense rafts. The tow boats are large stern-wheel vessels, requiring only about two feet of water. They are always placed back of the tow, and when traveling in a current of much velocity present a curious picture, their large wheels revolving in a reverse direction in order to bring the tow to a controllable speed.

A LENS for seeing when under water is described by its discoverer as producing an effect which is both astonishing and delightful. It gives distinct vision of objects twenty or thirty feet off, the eye's loss of extended sight when under water being because an entirely different focus is required. The spectacles which provide this can be made by putting two watch glasses of three-quarters of an inch diameter and an inch radius back to back, or with the concavities outward.

GENERAL QUESTIONS REGARDING THE USE OF THE WESTINGHOUSE AIR BRAKE AND TRAIN SIGNAL.

GENERAL QUESTIONS.

THE following catechism accompanied the report of the joint committees on "Air Brake Standards and Inspection and Care of Air Brakes on Freight Cars" at the recent conventions of the Master Car Builders' and Master Mechanics' Associations:

(All parties who have to do with the use, adjustment, care or repairs of air brakes should be thoroughly examined on these questions, in addition to the special questions for each class of men following them.)

1. Question. What is an air brake?

Answer. It is a brake applied by compressed air.

2. Q. How is the air compressed?

A. By an air pump on the locomotive.

3. Q. How does the compressed air apply the brakes?

A. It is admitted into a brake cylinder on each car, and it pushes out a piston in that cylinder, which pulls the brake on.

4. Q. How does the piston rod get back when the brakes are released?

A. There is a spring around the piston rod which is compressed when the brakes are applied, and when the air is allowed to escape to release the brakes, this spring reacts and pushes the piston in again.

5. Q. What was the first and simplest form of air brake?

A. The straight air brake.

6. Q. How was the straight air brake applied and released?

A. The engineer applied the brake by admitting air from the reservoir on the locomotive through a train pipe to all the brake cylinders, and he released the brakes by first shutting off the reservoir from the train pipe, and then opening the train pipe and all the brake cylinders to the atmosphere, so that the compressed air could escape again.

7. Q. Is the use of the straight air brake now allowable?

A. No.

8. Q. Why not?

A. Because it has been replaced by an improved form of brake called the automatic brake.

9. Q. Why is it called an automatic brake?

A. Because it is applied automatically by any derangement which reduces the air pressure in the train pipe, such as by the bursting of a hose or the parting of a train.

10. Q. What necessary parts has the automatic brake on a car which the straight air brake had not?

A. One auxiliary reservoir and one triple valve.

11. Q. Where is the compressed air kept ready for use in the automatic air brake?

A. In the main reservoir on the locomotive, in the smaller or auxiliary reservoir on each car and in the train pipe.

12. Q. Where does the compressed air come from directly, that enters the brake cylinder when the automatic brake is applied?

A. It comes from the auxiliary reservoir on each car.

13. Q. How does it get into the auxiliary reservoir?

A. It is furnished from the main reservoir on the locomotive through the train pipe when the brakes are released.

14. Q. How is the automatic brake applied and released?

A. The automatic brake is applied by reducing the air pressure in the train pipe at the locomotive or at any other point, and it is released by restoring the pressure on the train pipe from the main reservoir on the locomotive.

15. Q. Why does the compressed air not enter directly into the brake cylinder from the train pipe, as in the straight air brake?

A. Because the triple valve used with the automatic brake prevents the air from entering directly from the train pipe to the brake cylinder when the pressure in the train pipe is maintained or increased.

16 Q. What other uses has the triple valve?

A. It causes the brake cylinder to be open to the atmosphere under each car, and releases the brakes when the pressure in the train pipe is restored from the locomotive, and it opens communication from the train pipe to the auxiliary reservoir by the same movement; when the pressure in the train pipe is reduced, it closes the openings from the train pipe to the auxiliary reservoir and from the brake cylinder to the atmosphere, and then opens the passage between the auxiliary reservoir and the brake cylinder by the same movement, so as to admit the air and apply the brakes.

17. Q. How many forms of triple valves are there in use and what are they called?

A. Two: the plain triple and the quick-acting triple.

18. Q. How can you tell the plain triple from the quick-acting triple?

A. The plain triple has a four-way cock in it with a handle for operating the cock: the quick-acting triple has no such cock in it, but there is a plug cock in the crossover pipe leading from the train pipe to the triple when the quick-acting triple is used.

19. Q. What are these cocks for, in both cases?

A. They are to be used to cut out brakes on one car, without interfering with other brakes on the train, if the brake on that car has become disabled.

20. Q. How does the cock handle stand in the plain triple valve when the pipe is open for automatic action?

A. It stands in a horizontal position.

21. Q. In what position does the same handle stand when the brakes are cut out by closing the cock?

A. It stands at an inclined position midway between horizontal and vertical.

22. Q. Can this cock handle be placed in any other position, and what?

A. In the older form of plain triple valve it can be moved to a vertical position.

23. Q. What was this position for, and is it still used?

A. This was to convert the automatic brake into a straight air brake, and it was needed when some cars were equipped with straight air brake and some with automatic brake, but it is not now used.

24. Q. How does the handle of the plug in crossover pipe, used with the quick-acting triple, stand for automatic action?

A. It stands with the handle crosswise with the pipe, and the cock is then open.

25. Q. How does it stand when the cock is closed and the brake cut out of action?

A. It stands with handle lengthwise of crossover pipe.

26. Q. How is the train pipe coupled up between the cars?

A. By means of a rubber hose on each end of the train pipe, fitted with a coupling at the loose end.

27. Q. How is the train pipe closed at the rear end of the train?

A. By closing the cock in the train pipe at the rear end of the last car.

28. Q. How many such train pipe cocks are there to a car, on the air brake train pipe and on the air signal train pipe, and why?

A. Two for each pipe on each car, because either end of any car may sometimes be at the rear end of the train.

29. Q. How many kinds of train pipe cocks are there in use at the ends of the cars?

A. Two.

30. Q. Describe each and give the position of the handles for open and closed in each case?

A. The older form of train pipe cock is a straight plug cock in the train pipe not far from the hose connection; the handle stands crosswise with the pipe when it is open and lengthwise with the pipe when closed; it is now found principally on the air signal pipe. The other form of train pipe cock, now used on the air brake pipe, is an angle cock placed at the end of the train pipe and close to the hose. The handle of the angle cock stands lengthwise with the pipe when open, and crosswise with the pipe when closed.

31. Q. What uses have these train pipe cocks besides to close the pipe at the rear end of the train?

A. They are to be used to close the train pipe at both sides of any hose coupling which is to be parted, as when the train is cut in two.

32. Q. Why is it necessary to close the train pipe on both sides of the hose coupling before it is parted?

A. To prevent the escape of air from the train pipe, which would apply the brakes.

33. Q. How must the hose coupling be parted when it is necessary to do so, and why?

A. The air brake must first be released on the train, then the adjacent train pipe cocks must both be closed and the coupling must be parted by hand, to prevent the possibility of injury to the rubber gasket in the coupling.

34. Q. Why must the brakes be fully released before uncoupling the hose between the cars?

A. Because if the brakes are applied upon a detached car, they cannot be released without bleeding the auxiliary reservoir, and thus wasting air.

35. Q. In coupling or uncoupling the hose between cars, what must be done if there is ice upon the couplings?

A. The ice must first be removed and the couplings thawed out, so as to prevent injury to the rubber gaskets in uncoupling, and to insure tight joints in coupling the hose.

36. Q. What must be done with a hose coupling which is not coupled up, such as the rear hose of a train, or any hose on a car which is standing or running, but not in use?

A. It must be placed in the dummy coupling provided for it on each end of each car, in such manner that the flat pad on the dummy will close the opening in the coupling.

37. Q. Why is this important?

A. Because if it is not done properly, dust and dirt will enter the hose, and, when it is again coupled up in service, this dirt will be blown into the triple valve and interfere with its proper working, and will cause it to wear out more rapidly.

38. Q. What pressure should be carried in the train pipe and auxiliary reservoir?

A. Seventy pounds pressure to the square inch.

39. Q. Why should this pressure be 70 lb.

A. Because this pressure is necessary to get the full braking force which each car is capable of using, and, if it be exceeded, there will be danger of sliding the wheels.

40. Q. How much pressure can be obtained in the brake cylinder by the ordinary application of the brakes with 70 lb. in the auxiliary reservoir?

A. About 50 lb. pressure to the square inch.

41. Q. Why can only 50 lb. pressure be obtained under these circumstances?

A. Because the air at 70 lb. pressure in the auxiliary reservoir expands into a larger space when the auxiliary reservoir is opened to the brake cylinder, and, when the pressure has become equalized, it is thus reduced to 50 lb.

42. Q. How much must the train pipe pressure be reduced, in order to get 50 lb. pressure in the brake cylinder, in ordinary service?

A. Twenty pounds; or from 70 lb. down to 50 lb. in the train pipe also.

43. Q. Can the brakes be applied so as to get only a portion of this 50 lb. pressure in the brake cylinder, and how?

A. They can be so applied by reducing the train pipe pressure less than 20 lb.

44. Q. If the train pipe pressure be reduced 10 lb. what will the pressure be in the brake cylinder?

A. About 25 lb.

45. Q. How is this graduated action obtained?

A. By means of the graduating valve in the triple valve.

46. Q. Is it important to keep all the air brake apparatus tight and free from leaks?

A. Yes.

47. Q. Why is this important?

A. In order to get full service from the air brakes, and prevent the waste of air, and also to prevent the brakes applying automatically by reason of leak in the train pipe.

48. Q. Is it important to know that the train pipe is open throughout the train and closed at the rear end before starting out?

A. Yes; this is very important.

49. Q. Why is this very important?

A. Because if any cocks in the train pipe were closed, all the brakes back of the cock which is closed would be prevented from working.

50. Q. How can you know that the train pipe cocks are all open when the train is made up?

A. By testing the brakes; that is, by applying and releasing them, and observing whether they all operate.

51. Q. Do you understand that no excuse will be acceptable for starting out the train without first testing the air brakes?

A. Yes.

52. Q. Why is this rule absolute?

A. Because the safety of passengers and property depends upon the brakes being properly coupled up and in an operating condition before the train is started.

53. Q. At what other times should the brakes be tested, and how?

A. Before starting the train down a heavy grade, and the test should be made with a full application of the brakes.

54. Q. How much air pressure should be carried in the air signal train pipe?

A. Twenty-five pounds pressure.

55. Q. Is it important that this train pipe and its connections be also kept tight?

A. Yes.

56. Q. How far should the brake piston travel in the cylinders on cars and tenders with a full application of the brake?

A. Not less than 4 in. nor more than 8 in.

57. Q. Why should they travel not less than 4 in.?

A. Because it is necessary to have them travel 4 in. in order to fully close the leakage groove provided in the brake cylinder for the escape of small amounts of air which may leak through the triple valve. If these grooves were not closed, the brakes would soon leak off after they are applied.

58. Q. Why should the piston travel not more than 8 in.?

A. Because if it travels further than this a little wear of the brake shoes will cause the piston to travel far enough to rest against the back cylinder head, when the brakes are applied, and this cylinder head would then take the pressure instead of its being brought upon the brake shoes.

59. Q. How far should the driver brake piston travel with a full application of the brakes, and why?

A. Not less than one-third of the full stroke of the piston nor more than two-thirds of its full stroke, for reasons similar to those given for cars and tenders.

60. Q. If the brakes stick upon any car so that the engineman cannot release them at any time, how are you to release them?

A. By opening the release cock in the auxiliary reservoir, and holding it open until air begins to escape from the triple valve, and then closing it again.

61. Q. What is the pressure retaining valve, and what is its use?

A. The pressure retaining valve is a small valve placed at the end of a pipe from the triple valve, through which the exhaust takes place from the brake cylinder. It is used to retard the brake release on heavy grades and hold the brakes partially applied, so as to allow more time for the engineman to recharge the auxiliary reservoir.

62. Q. What precautions are necessary on every train in regard to hose couplings?

A. Every train must carry at least two extra hose and couplings complete, for use in replacing any hose couplings which may fail or become displaced. These extra hose and couplings to be carried on such part of the train as is required by the rules and regulations.

SPECIAL FOR ENGINEMEN.

63. Q. How should the air pump be started?

A. It should be started slowly, so as to allow the condensation to escape from the steam cylinder, and prevent pounding, which is more likely to occur when the air pressure is low.

64. Q. Why should the piston rod on the air pump be kept thoroughly packed?

A. To prevent condensation in the steam cylinder from running down the rod into the air cylinder, and thus getting water in the air brake service.

65. Q. How should the steam cylinder of the air pump be oiled, and what kind of oil should be used?

A. It should be oiled as little as necessary through a sight feed lubricator, and cylinder oil should be used.

66. Q. How should the air cylinder of the air pump be oiled; what kind of oil, and why?

A. It should be oiled very little, by once filling the oil cup with West Virginia well oil daily. The oil must never be introduced through the air inlet ports, as this practice would cause the valves to gum up.

67. Q. What regulates the train pipe pressure?

A. The pump governor.

68. Q. At what pressure in the train pipe must the pump governor stop the pump, and do you understand the importance of keeping this pump governor in order and operating at that pressure?

A. It must stop the pump at a pressure of 70 pounds in the train pipe, and it must be kept clean and adjusted to this pressure in order to get the best service from the air brakes.

69. Q. Why is the equalizing engineer's valve better than the older forms?

A. Because it enables the engineer to apply the brakes more uniformly throughout the train and with less shock to the train, especially when the quick-acting triple valves are used. It also prevents the brakes from being kicked off on the forward end of the train when the engineer closes the valve.

70. Q. Why does the equalizing engineer's valve produce these results in ordinary service stops?

A. Because the engineer does not, in such cases, open the train pipe to the atmosphere direct, but he only reduces the air pressure above the piston in the engineer's valve, which causes that piston to open the train pipe to the atmosphere, and to close the opening gradually when the train pipe pressure has been correspondingly reduced.

71. Q. What does the excess pressure valve in the engineer's valve accomplish, and do you regard it important to have it working properly?

A. It maintains an excess pressure of about 20 pounds in the main reservoir above the pressure in the train pipe, and it is important that it be kept clean and in working order, so as to have this excess pressure to insure release and for use in recharging the train quickly after the brakes are released.

72. Q. How often should the brake valve be thoroughly cleaned and oiled?

A. At least every two months.

73. Q. If the rotary disk valve in the engineer's valve is unseated by dirt or by wear, what may be the result, and what should be done?

A. It may be impossible to get the excess pressure; when the brakes have been applied they may keep applying harder until full on, or when they have been applied they may go off. The rotary disk valve should be thoroughly cleaned, and if worn it should be faced and ground to a seat.

74. Q. If the piston in the engineer's valve becomes gummed up or corroded from neglect to clean it, what will be the result?

A. It will be necessary to make a large reduction of pressure through the preliminary exhaust port before the brakes will apply at all, and then the brakes will go on too hard and will have to be released.

75. Q. When the engine is standing alone and the pump is running, why must the engineer's valve not be left standing in the lap position (No. 3)?

A. Because the main reservoir pressure may become so high that, when the handle of the engineer's valve is again placed in the release position, it will cause the train pipe and tender auxiliary reservoir to be charged with too high pressure, which might injure the adjustment of the pump governor as well as cause the tender wheels to be slid with the first application of the brakes.

76. Q. When the engine is coupled to the train, why is it necessary to have the full train pipe pressure and the excess pressure on the main reservoir?

A. So that the brakes will all be released and the train quickly charged when the engineer's valve is placed in the release position.

77. Q. When the train is charged, and the train pipe pointer of the air gauge begins to rise, how must you test the train pipe for leaks?

A. By placing the handle of the brake valve in the lap position, and by observing whether the black pointer stands still or falls back. The more rapidly it falls back, the greater is the leak indicated.

78. Q. Why should the driver brakes always be operated automatically with the train brake?

A. Because it adds greatly to the braking force of the train and the brakes can be applied alike to all the wheels for ordinary stops, and in an emergency the greatest possible braking force is at once obtained by one movement of the handle.

79. Q. In making a service application of the brakes, how much reduction of the train pipe pressure from 70 pounds does it require to get the brakes full on?

A. About 20 pounds reduction.

80. Q. What should the first reduction be in such an application, and why?

A. From six to eight pounds, so as to insure moving the pistons in the brake cylinders past the leakage groove, yet not apply the brakes too hard until the slack in drawbars and drawsprings is first taken up.

81. Q. What is the result of making a greater reduction of pressure than 20 pounds?

A. A waste of air in the train pipe, without getting any more braking force, and therefore requiring more air to release the brakes.

82. Q. How many applications of the brakes are necessary in making a stop?

A. Generally only one; by applying them lightly at first with six or eight pounds reduction of air in the train pipe, and afterward gradually increasing the force of the application. Two applications are as many as should ever be required.

83. Q. Why is it dangerous to apply and release the brakes repeatedly in making stops?

A. Because every time the brakes are released the air in the brake cylinder is thrown away, and, if it is necessary to apply them again before sufficient time has elapsed to recharge the auxiliary reservoirs, the application of the brakes will be weak, and after a few such applications the brakes are almost useless, on account of the air having been exhausted from the auxiliary reservoirs.

84. Q. In releasing and recharging the train, how long should the handle of the engineer's valve be left in the release position?

A. Until the train pipe pressure has risen nearly to 70 pounds again.

85. Q. In making service stops why should you release the brakes a little before coming to a full stop?

A. So as to prevent stopping with a lurch; it also requires less time for the full release of the brakes after stopping.

86. Q. In making service stops, why must the handle of the engineer's valve not be moved past the position for service applications?

A. So as to prevent unnecessary jerks to the train, and the emergency action of the triple valve when not necessary.

87. Q. If you find the train dragging from the failure of the brakes to release, how can you release them?

A. By placing the handle of the engineer's valve in the running position until full excess pressure is attained, and then throwing it quickly into the release position.

88. Q. When the brakes go on suddenly when not operated by the engineer's valve, and the gauge pointer falls back, what is the cause, and what should you do?

A. Either a hose has burst, or a conductor's valve has been opened, or the train has parted. In any event, the handle of the engineer's valve must be immediately placed in the lap position to prevent the escape of air from the reservoir.

89. Q. Are the brakes liable to stick on after an emergency application, and why?

A. The brakes are harder to release after a severe application, because they are on with full force, and it requires higher pressure than usual in the train pipe to release them again. In this case it is necessary always to have in reserve the excess pressure on the main reservoir to aid in releasing the brakes. With the quick acting triple valve this is especially necessary, because air from the train pipe as well as from the auxiliary reservoir is forced into the brake cylinder when a quick application of the brake is made, thus increasing the pressure in the brake cylinder, and requiring a high pressure in the train pipe afterward to cause the brakes to be released.

90. Q. In using the brakes to steady the train while descending grades, why should the air pump throttle be kept well open?

A. So that the pump may quickly accumulate a full pressure in the main reservoir for use in recharging the train when the brakes have been released again.

91. Q. In descending a grade how can you best keep the train under control?

A. First, by commencing the application of the brakes early, so as to prevent too high a speed being reached. Second, by applying the brakes lightly first, then increasing the brake pressure as needed, and by slowing the train down just before it is necessary to release the brakes for recharging, so as to give them time enough to refill the auxiliary reservoirs before much speed is again attained.

92. Q. If the train is being drawn by two or more engines, upon which engine should the brakes be controlled, and what must the enginemen of the other engines do?

A. The brakes must be controlled by the leading engine, and the enginemen of the following engines must close the cock in the train pipe just below the engineer's valves. The latter must always keep his pump running and in order, and main reservoir charged, with the engineer's valve in the running position, so that he may quickly operate the brakes if called upon to do so.

93. Q. If the air signal whistle gives only a weak blast, what is the probable cause?

A. Either the reducing valve is out of order, so that the pressure is less than 25 pounds, or the whistle itself is filled with dirt.

94. Q. If the reducing valve for the air signal is allowed to become clogged up with dirt, what will the result probably be?

A. The signal pipe might get the full main reservoir pressure, and the whistle will blow when the brakes are released.

95. Q. If you discover any defect in your air brake or signal apparatus while on the road, what must you do?

A. If it is something that cannot be readily remedied at once, it must be reported to the engine house foreman as soon as the run is completed.

96. Q. What is the result if water be allowed to collect in the main reservoir of the brake apparatus?

A. The room taken up by the water reduces the capacity for holding air, and the brakes are more liable to stick. In cold weather, also, the water may freeze and prevent the brakes from working properly.

SPECIAL FOR ENGINE REPAIRMEN.

97. Q. How often must the air brake and signal apparatus on locomotives be examined?

A. After each trip.

98. Q. Under what pressure must it be examined?

A. Under full pressure, *i. e.*, 70 lb. on the air brake train pipe, 20 lb. excess in the main reservoir, and 25 lb. pressure upon the air signal train pipe.

99. Q. How will you be sure that proper pressures are upon the two train pipes?

A. By regulating, and if necessary, cleaning the pump governor so that it will shut off steam from the pump when 70 pounds train pipe pressure is reached, and by examining, and if necessary cleaning the pressure reducing valve for the signal train pipe, so that it maintains 25 pounds pressure in the train pipe.

100. Q. If you do not obtain 20 pounds excess pressure in the main reservoir when the handle of the engineer's valve is in the running position, what is the cause?

A. Either the excess pressure valve needs cleaning or the rotary disk valve in the engineer's valve is unseated, and allows air to leak from one port to another.

101. Q. Why must the air pump piston rod be kept well packed?

A. To prevent condensation in the steam cylinder from running down into the air cylinder and getting into the brake service.

102. Q. How often must the main reservoir and the drain cup under the tender be drained?

A. After each trip.

103. Q. How often must the triple valves and the cylinders of the driver and tender brakes be cleaned and oiled?

A. They must be thoroughly cleaned and oiled with a small amount of well oil once every six months, and the cylinders must be oiled every three months. If the driving brake cylinders are so located that they become hot from the boiler, they may require oiling more frequently.

104. Q. If there are any leaks in the pipe joints or anywhere in the apparatus, what must you do?

A. Repair them before the engine goes out.

105. Q. How is the brake shoe slack of the cam driver brake taken up, and what precautions are necessary?

A. By means of the cam screws, and it is necessary to lengthen both alike, so that when the brake is applied, the point of contact of the cams will be in a line with the piston rod.

106. Q. How is the brake shoe slack of driver brakes on a locomotive with more than two pairs of driving wheels taken up?

A. By means of turnbuckle or screw in the connecting rods.

107. Q. How is the slack of the tender brake shoes taken up?

A. By means of the dead truck levers; if they will not take it up enough, it must be taken up in the underneath connection, and then adjusted by the dead lever.

108. Q. What travel of piston should the driver brakes be adjusted for?

A. For not less than one-third nor more than two-thirds of the full stroke of the piston.

109. Q. What travel of piston should the tender brakes be adjusted for?

A. Not less than 4 in. nor more than 8 in.

SPECIAL FOR TRAINMEN.

110. Q. How should you proceed to test the air brakes before starting out, or before descending a heavy grade?

A. After the train has been fully charged with air, the engineman must be signaled to apply the brakes; when he has done so, the brakes must be examined upon each car to see that the air is applied, and that the piston travel is not less than 4 in. nor more than 8 in. The engineman must be then signaled to release the brakes, and this signal must be given by the train air signal from the rear car, if it is in use upon the train; after he has done so, each brake must be examined again to see that all are released. The engineman and conductor must then be notified that the brakes are all right, if they are found so.

111. Q. In starting out a passenger train, how many cars must have the brakes in service?

A. Every car upon the train.

112. Q. When might you cut out a brake upon a passenger train?

A. Never; unless it gets out of order while on the run, in which case it must be reported to the inspector at the end of the run, or upon the first opportunity which may give sufficient time to repair it.

113. Q. If a hose bursts upon the run, what must be done?

A. The hose must first be replaced by a good one, and the engineman then signaled to release the brakes. The train must not proceed until the brakes have been reconnected and tested upon the train to see that all are working properly.

114. Q. If the train breaks in two, what must be done?

A. The cock in the train pipe at the rear end of the first section must be closed, and the engineman signaled to release the brakes. The two parts of the train must then be coupled, the hose connected and the brakes again released by the engineman. After the train has been completely coupled up and the brakes are released, all brakes must be tested before continuing the run.

115. Q. Explain how the pressure retaining valves are thrown into action or thrown out of action, and when this must be done.

A. The pressure retaining valve is thrown into action by turning the handle of the valve to a horizontal position, and it is thrown out of action again by placing this handle in a vertical position, pointing downward. This handle should be placed in a horizontal position at the top of a heavy grade, and it should always be returned to a vertical position at the foot of the grade, as otherwise the brakes will drag on any cars which still have the handle of the pressure retaining valve in the horizontal position.

116. Q. If the brake of any car is found to be defective on the run, how should you proceed to cut it out?

A. By closing the cock in the crossover pipe of the quick acting brake, or in the triple valve of the plain automatic brake, and then opening the release cock in the auxiliary reservoir upon that car until all the air has escaped from it.

117. Q. What is the conductor's valve, and what is its use?

A. It is a valve at the end of the branch pipe leading from the train brake pipe upon each car; it is to be opened from the car in any emergency when it is necessary to stop the train quickly, and only then. When used it should be held open until the train is stopped, and then it should be closed.

118. Q. What is the air signal for, and how is it operated?

A. It is to signal the engineman, in place of the old gong signal, and it is operated by pulling directly downward on the cord one second for each signal given and allowing two seconds to elapse between pulls.

119. Q. If the car discharge valve on the air signal system is out of order or leaking on any car, how can you cut it out?

A. By closing the cock in the branch pipe leading from the train signal pipe to the discharge valve; to do so the handle of this cock should be placed lengthwise with the pipe.

120. Q. How is the slack taken up so as to secure the proper adjustment of piston travel?

A. By means of the dead truck lever, and if that is not sufficient, one or more holes must be taken up in the underneath connection and the adjustment then made by the dead truck lever.

SPECIAL FOR INSPECTORS.

121. Q. Do you understand that no passenger train may be started out with any of the brakes out of service?

A. I do.

122. Q. Why is it important that no leaks should exist in the air brake service?

A. Because they would interfere with the proper working of the brakes and might cause serious damage.

123. Q. What must be done with the air brake or air signal couplings when not united to other couplings?

A. They must be secured in the dummy coupling, so that the face of the dummy coupling will cover the opening of the hose coupling so as to prevent dust and dirt from entering the hose.

124. Q. If air issues from the release port of the triple valve when the brakes are off, what is the cause?

A. It is probably due to dirt on the rubber-seated emergency valve.

125. Q. How often must the cylinder and triple valves be examined, cleaned, and oiled?

A. Once every six months, and the cylinders must be oiled once every three months with a small quantity of well oil. The dates of the last cleaning and oiling must be marked with chalk on the cylinders.

126. Q. To what travel of piston must the brakes be adjusted?

A. Not less than four inches nor more than eight inches.

127. Q. How is the slack taken up so as to secure this adjustment?

A. By means of the dead truck lever, and if that is not sufficient, one or more holes must be taken up in the underneath connection and the adjustment then made by the dead truck lever.

128. Q. What are the different holes in the outer end of the cylinder levers for, and why must the connections be pinned to the proper hole for each car?

A. These holes are to enable the adjustment of the brake pressure to be made according to the weights of different cars. The connection must be made to the proper hole in each case, according to the weight of the car, so as to give proper braking power, otherwise the brake will be inefficient, or the wheels may be slid under the cars.

DR. GRADENIGO, professor of ophthalmic surgery in the University of Padua, has just succeeded in transplanting the cornea from the eye of a barn fowl into the eye of a patient under his care. On the eighth day after the operation the transplanted cornea presented a quite pellucid and convex appearance. Such a result has not yet been recorded in the annals of Continental surgery.—*London Surgery.*

THE FRENCH WAR SHIP JEAN BART.

THIS first-class cruiser belongs to an absolutely new type; commenced June 6, 1888, in the government dock yards at Rochefort, it was launched the 24th of October, 1889. Its final equipment was accomplished under the direction of Commandant Servan, and it will soon make its first trial.

The Jean Bart is constructed of steel, and its displacement is 4,100 tons. The machinery, constructed in the government shops at Indret, is nominally of 2,000 horse power, but virtually of 8,000, and should give the vessel a speed of 19½ knots, or a little more than 35 kilometers an hour. The crew is composed of 331 men, of which 16 are officers. The armament is comprised of 4 cannons of 16 centimeters, 6 of 14 centimeters, 8 for rapid firing from the topmast and bridge, 8 revolvers on the small bridge, and two small mountain pieces for the landing crew; 5 tubes for projecting torpedoes—two upon the bow, two upon the stern, and one for either side; 6 electrical projectors; 11 landing boats, of which one is a steam launch and one a torpedo guard.

The Jean Bart measures 105·40 m. in length, by 13·28 m. beam. Its draught of water at the stern is 6·14 m. The plans were drawn by Mr. Thibaudier, an engineer of the highest standing.

NEW BRITISH CRUISERS.

THE second-class twin-screw cruiser Intrepid was launched at the works of the London and Glasgow Engineering and Iron Shipbuilding Co., Govan, on the 20th ult. She has been built under the "Hamilton" programme, from designs prepared under the supervision of Mr. W. H. White, Director of Naval Construction, and is of the following dimensions: Length, between perpendiculars, 300 ft.; breadth, extreme, 43 ft. 8 in.; depth, moulded, 22 ft. 9 in.; with a displacement of 3,600 tons. As in her sister vessels, the Indefatigable and Iphigenia, the hull is sheathed with teak planking, and covered with copper from the keel to with all the most recent appliances to meet the demands of modern naval warfare. A vessel of the same dimensions, speed, power, armament, and general equipment as the Intrepid, and named the Brilliant, was successfully launched from the Royal Dockyard at Sheerness on the 24th ult.

At Pembroke building operations have been commenced upon a new second-class cruiser, 320 ft. in length, and with a tonnage of 4,360 tons. She is to be named the Flora, and will be armed with two 6 in. quick-firing guns, mounted on the poop and forecastle as bow and stern chasers, eight 4·7 in. quick-firing guns for broadside fire, and nine 6 pounder and 3 pounder guns, besides four torpedo tubes. Her estimated speed is 19½ knots with forced draught, and 18 knots with natural draught. Preparations are also being made at Chatham for the laying down of a steel cruiser, to be named the Forte, similar in every respect to the Astrea and Bonaventure, now under process of construction at Devonport.

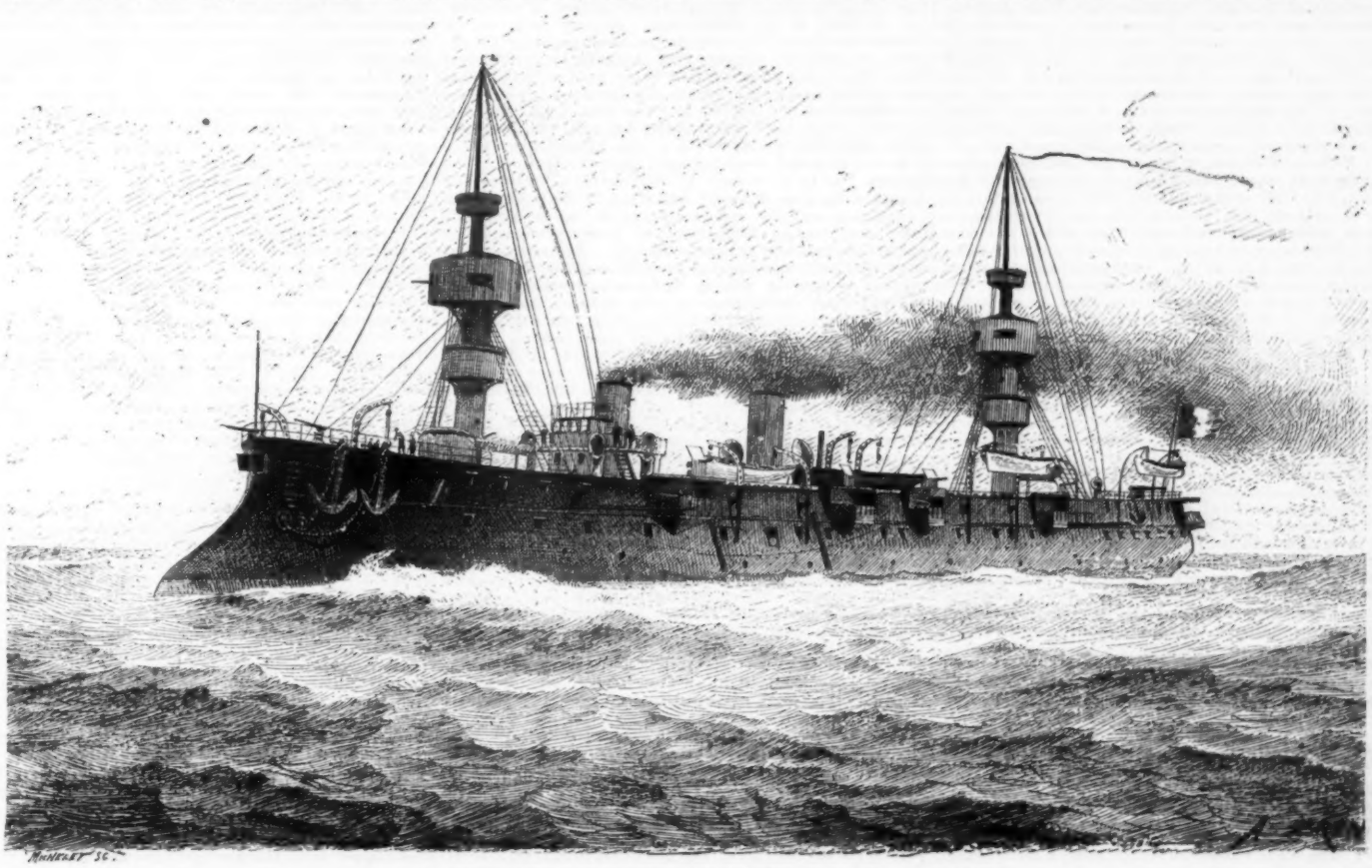
The Melampus, steel twin-screw cruiser, built and engined by the Naval Armaments Co., at Barrow, has successfully passed through her eight hours' natural draught trial at Portsmouth, when, with a foul bottom, a speed slightly exceeding 18 knots was registered by patent log, the engines developing 7,600 horse power, or 600 in excess of the contract, with a vacuum of 27½ in., the boiler pressure being 147 lb. per square inch. Before proceeding on her forced draught trial she will be clean painted and the pitch of her propeller altered from 17 ft. to 18 ft., with a view of mitigating the sensational vibration experienced on her last trial. The speed expected on the forthcoming trial is 19½ knots, with the engines developing collectively 9,000 horse power.—*Industries.*

THE COPPER RESOURCES OF THE UNITED STATES.*

By Mr. JAMES DOUGLAS, New York City.

THE development of the copper resources of this country has kept close pace with the unfolding of its geographical area to commerce. In colonial days, when our English ancestors occupied only the Atlantic seaboard, insignificant quantities of copper were mined in Connecticut, New Jersey and Pennsylvania, and the ore was shipped for treatment to England. The first steam pumping equipment erected in this country was probably that used by Josiah Hornblower, in the year 1753, at the copper mines at Belleville, New Jersey, almost within sight of this city. That copper in the native state existed on Lake Superior was mentioned in the *Relations des Jesuites* as early as 1659 or 1660. The Rev. Claude Allouez described a stray mass in 1666. But it was not until 1771, a little more than a century later, when this region had passed from the dominion of France to that of Great Britain, that Alexander Henry organized a company in England, with the Duke of Gloucester, Charles Townshend, and other notables as incorporators, to mine copper on the Ontonagon River, the region whence came the stray blocks which had grown so famous by repeated mention in the *Relations* and by the reports of various travelers. Failing in 1771 to find the copper in place, Henry renewed operations on the following year on Michipicoten Island, on the north shore, but only to experience another failure. What little copper ore he raised was shipped to England, where ship and cargo were seized and sold for the company's debts. Mr. Townshend's losses in his Lake Superior venture may have embittered his feelings toward America, and perchance have been one of the indirect causes of the unreasonable financial policy toward the colonies, which precipitated the revolutionary war, and for which he, as president of the board of trade and subsequently as chancellor of the exchequer, was responsible.

Then stagnation followed for three-quarters of a century. Even if no other cause had interfered, the unsettled ownership of the lake region must have retarded mining until the date at which it actually commenced, in 1844. For it was not until 1796 that Michigan was ceded by Great Britain to the United States; not till 1837 that Michigan was admitted to statehood, and not until 1842 that the Indian titles to the land were extinguished. Meanwhile steamers had replaced canoes on the lake and in 1841 Dr. Houghton had given the world the first authentic and scientific account of the geological structure of the Keweenaw series of rocks and of the mode of occurrence of their native copper. In 1844 the Cliff mine was opened, and in 1845 lake copper appears as an item in the world's production. That in those days our copper enterprises were in an infantile condition is shown by the fact that although in 1850 the lake produced only 570 tons, yet that small quantity was over 88 per cent. of the total production of this country. Leplay, secretary of the commission of mining statistics in France, estimates the world's production at that date at 52,400 tons and assigns to this country a consumption of 6,100 tons, which was supplied by about 5,500 tons of imported and 600 tons of domestic copper.* After 1850, and until the yield of the Calumet and Hecla mine began to be felt, in 1867, the relative production of the lake region fell off, owing to the appearance successively of Vermont, the Southern States and California in the list of producers. Vermont copper came almost entirely from the Ely mine, in the Vershire district. This mine was discovered in 1820, but began to be worked only in 1850, and thenceforward yielded from year to year an increasing quantity, till 1850, when its output amounted to 3,186,175 pounds. It was closed in 1882, but is now being reopened. By far the largest producer in the Southern States during this period was the Ducktown group of mines, in Tennessee. Discovered about 1846, systematic work was be-



THE FRENCH WAR STEAMER JEAN BART.

about 3 ft. above the normal load water line, and this will enable her to keep the sea for a considerable period on remote stations where there is an entire absence of docking accommodation. The stern post, stem, ram, and A brackets for carrying the propellers are of phosphor bronze, and the propellers of gun metal. In her design speed was primarily considered, and in consequence she will be fitted with two sets of triple-expansion engines capable of developing 9,000 horse power under forced draught, the resulting speed being estimated at 20 knots.

The engines, which are separated by a fore-and-aft bulkhead extending to the upper deck, are supplied with steam by five cylindrical steel boilers working at a pressure of 150 lb. per square inch. Special protection is afforded the cylinders where they protrude above the protective steel deck by an armored breastwork built up of 5 in. of compound armor, 7 in. of teak backing, and two thicknesses of ½ in. steel plating. The protective steel deck, which runs right the whole length of the ship, terminates forward in the ram, and is 1 in. thick on the top and 2 in. thick on the slopes. There are in all about eighty water-tight compartments, with a double bottom extending throughout the machinery space.

The armament will consist of two 6 in. breechloading central pivot guns, six 4·7 in. quick-firing guns, eight 6-pounder Hotchkiss guns, one 9-pounder gun, and four 5-barreled Nordenfeldt guns, together with four 18-in. torpedo tubes for the projection of Whitehead torpedoes. Accommodation is provided for a crew of 253 officers and men, and when ready for sea the Intrepid will prove a valuable addition to the growing list of British cruisers, as she will be replete

* Paper read provisionally before the American Institute of Mining Engineers, at the New York meeting, September, 1890, and completed with the statistics for 1890.

* Foster and Whitney Report, Part I, Copper Lands, p. 137.

the laying of its track through Arizona and New Mexico. Previous to this, the Longfellow mine at Clifton, Arizona, had been worked, and its copper bullion carted 700 miles to the nearest railroad terminus in Kansas. The richer argentiferous copper ores of Butte, Montana, had also been hauled a distance of more than 400 miles to Corinne, on the Central Pacific railroad. But mining operations were necessarily restricted in each district to exceptionally rich ores, until the arrival of the railroad introduced mineral fuel. Arizona and Montana immediately responded to the stimulus of cheap transportation, and mining and smelting on an extensive scale commenced in the extreme south and the extreme north of our wide Western domain. The next event which marked a stride in our progress toward pre-eminence in the copper world occurred in 1883. It was the discovery of large bodies of copper ore in the Anaconda mine, the central and culminating point of the immense Butte lode. With a bound this great mine sprang to second place in the rank of production, and within five years overtook and passed its great competitor, the Calumet and Hecla. Since then the growth of production in both the lake region and the West has shown no abatement, but the relative increase has been in favor of Butte and against the lake. In 1881, therefore, these three sources of supply—namely the native copper deposits of the lake region, the oxidized ores of southern Arizona, and the sulphureted ores of Montana—constituted our chief resource, and they remain so to-day. In 1889 our total production was divided as follows:

	Per cent.
The Lake region	35·81
Montana	43·07
Arizona	13·34
All other native ores	5·69
Imported ores	2·09
Total	100·00

LAKE SUPERIOR.

In reviewing Lake Superior mining we find that three groups of mining companies have been successfully formed, and that each group began operations on a separate one of the three distinct forms of deposit in which copper occurs in the rocks of the Keweenaw series. The first group of companies worked veins in search of mass copper; the second group worked the ash beds of Keweenaw county and their equivalent amygdaloid beds in the Portage district; and the third group of companies worked the conglomerate beds.

Mass Mines.—The only mine of the first group now producing any considerable quantity of copper is the Central. The Cliff, which was the first mine systematically worked on the lake, having begun to produce copper in 1844, has yielded very little within the past decade. The same is true of the still more famous Minnesota, opened in 1848 in Ontonagon county on an interbedded vein; of the Phœnix, opened in 1844; the Northwestern and Copper Falls in 1845; the Northwest in 1847; the Ridge in 1850; the National and Evergreen Bluff in 1853; the Mass in 1856; and of a host of small mines which never added much to the copper supply, but did add largely to the assessment roll. All these companies commenced operations in search of mass copper either on the transverse veins of Keweenaw county toward the point of the promontory, or on the interbedded veins of the Ontonagon country toward the base of the promontory. The Copper Falls Company, failing in its quest, turned its attention to one of the amygdaloidal beds through which the vein cut, and which at the point of intersection seemed to enrich it. Thus, though the Copper Falls Company remains to-day a small producer, the Central is the only one of the original group of mass mining companies which still actively works a vein. The other mass mines yield but a trifle, and this is recovered by tributers. The experience of other mass mines has been confirmed by the Central, namely, that the masses grow fewer as depth is attained, and that they are distributed in the veins in no regular or assignable order. The Central may not have produced as many large masses as the Cliff and the Minnesota, but it yielded at least one even larger than the famous 500 ton mass of the latter mine. It consisted of a nucleus from which 600 tons of copper were cut, and a number of subordinate masses that were connected with the central mass by distinct filaments. The total amount of copper yielded by this series of related masses was about 1,200 tons. Even in its most prosperous days the product of the Central was about evenly divided between mass and stamp copper. The vein varies in width from a mere seam to 25 feet, and the productive chute of ore below the 900 foot level does not average more than 300 feet in length. The possibilities for a large production do not, therefore, exist if operations are confined to this vein alone; but exploration for other veins is being vigorously pushed. The mine has reached the thirty-first level—a vertical depth of 2,900 feet. Above the thirtieth level (2,800 feet deep) the vein was shattered in passing through a bed of amygdaloid, and on that level was completely obliterated by an underlying bed of conglomerate. Fears were entertained that the bottom of the mine had been reached, but recently the vein has been cut in sinking the shaft below the 2,800 foot level. It was thrown 240 feet to the west. Where rediscovered it is of average size and productiveness. The mine has yielded over 20,000,000 lb. of copper, and has proved so profitable from the start that even the first year's expenditure was repaid by the first year's returns. Though the vein has generally been narrow and the yield on the average only 1·9 per cent., the management has been so excellent, and the cost of extraction so low, that dividends amounting to $2,000,000 have been paid on a capital of $100,000.

Amygdaloid Mines.—The second group of companies was formed to work the ash beds of amygdaloidal diabase, which though traceable throughout the whole length of the Keweenaw series of rocks, appear to be richer in copper on the shores of Portage Lake than elsewhere. As already remarked, the Copper Falls (a mass company) diverted its attention early in 1851 to the working of an ash bed. Although the extravagant hopes which were based upon excessive estimates of the yield of the ash bed were not realized, this company's endeavor stimulated speculation and honest work on the amygdaloid beds of Keweenaw county and of Portage Lake district. Many companies were speedily organized for the purpose of developing these properties. Contrary to the fate of the mass companies, most of them have maintained a more or less vigorous existence to this day. Of the companies which appear in the list of producers within the past decade, the following belong to the second group, and date back their beginning to the second period of Lake mining, between the years 1850 and 1865: Isle Royal Company, which commenced work in 1852; Grand Portage Company, which commenced work in 1853; Sheldon and Columbian Company, which commenced in 1853; Pewabic Company, which commenced work in 1853; Huron Company, which commenced work in 1855; Quincy Company, which, though organized in 1848, commenced active work only in 1856; Franklin Company, which commenced work in 1857; Albany and Boston Company, which commenced work in 1860; South Pewabic Company (now the Atlantic), which commenced work in 1865. The Kearsarge and Wolverine are the only mines recently opened on an amygdaloid bed in the Portage district. The former made its first return of 829,125 lb. of copper from a rock yielding 1·02 per cent. in 1888. Of this group of mines by far the most remunerative has been the Quincy, but the one which exhibits the most extraordinary minimum cost of production is the Atlantic. These mines are situated on opposite sides of Portage Lake. The Quincy crowns the summit of a hill which rises boldly from the lake at the point where the town of Hancock seems with difficulty to be climbing up its steep slope. The Atlantic is on the southern shore of the lake, to the southwest of the Quincy and on a more westerly bed. Both mines are in a rock which is similar in appearance and structure. The Quincy amygdaloid differs from the Atlantic, however, in that it carries 40 per cent. of its copper in masses and what is known as "barrelwork"—that is, metal in blocks so coarse that the earthy matter can be separated under the hammer without dressing. It can therefore be hand-sorted. Nearly all the Atlantic rock passes without selection through the stamp mill, and the product is almost exclusively "stamp work." The Quincy bed, as might be anticipated from the mode of occurrence of its copper contents, is more variable in size and yield than the Atlantic, which, though much poorer, is remarkably uniform in its percentage. Quincy rock, as delivered to the mill, yields on an average about 2 per cent., of metallic copper; the Atlantic only 0·75 per cent. which this year fell to 0·60 per cent. Both mines are worked to a great depth; the Quincy's lowest level is 3,900 feet on the incline, and the Atlantic's 1,600 feet. In both mines the rock is easily broken, but the character, uniformity and width of the Atlantic bed allow it to be extracted more cheaply than the Quincy. The Quincy has to be sorted at the surface, whereas the Atlantic ore goes without handling to the mill. Both the mining and the concentrating of the Atlantic ore can, therefore, be carried on at lower cost, and this partially offsets its greater leanness. Yet nothing but most excellent management has brought down the total cost of mining, raising, and concentrating the ore; of delivering concentrate to the furnace and smelting it, and of transporting to market and selling the refined copper, to $1.43 per ton of rock treated That was the figure in 1888. In 1889 it was $1.53. The Quincy has just completed a new and well equipped three stamp mill, with a capacity of 180,000 tons a year, which will enable it to increase its output of copper beyond the 3,200 tons limit of 1889. The Atlantic will probably remain steady at about 1,800 tons of copper produced from 280,000 tons of ore. I have selected for comparison these two typical amygdaloid mines without disparagement to others, such as the Osceola, which are paying dividends out of rock yielding little more than 1 per cent. of copper.

Conglomerate Mines.—The Albany and Boston forms just such a link between the second and third groups of mines as the Copper Falls forms between the first and second groups. After failing to work profitably an amygdaloid bed, the Albany and Boston made the first experiment in 1864 in working a conglomerate bed, and this, though unsuccessful itself, was the forerunner of the most successful and important enterprise on the lake. The Albany and Boston should therefore appear at the head of the group of conglomerate mines, followed by the Calumet and Hecla in 1865 and by the Allouez, which, though organized in 1859, commenced work on the Allouez conglomerate only in 1869. The Osceola appeared in 1873, but after working for a time on so much of the remunerative portion of the Calumet conglomerate as lay within its lines, it transferred its operations to an amygdaloid bed. The Tamarack, which tapped the Calumet and Hecla conglomerate on the dip of the great ore chute by a vertical shaft, and commenced making copper in 1885, is the latest born of the conglomerate mines. Several conglomerate beds alternate throughout the series of the Keweenaw rocks with the unaltered traps and with the copper-bearing amygdaloid. In many places they carry traces of copper, but the only one that gives assurance of economic value is the Calumet bed, where, for about three miles along its strike, it outcrops on Calumet and Hecla ground, and on the northern edge of the bordering Osceola ground to the south, and the southern edge of Centennial ground to the north. In the center of this long stretch Calumet shaft No. 1 was sunk in what has proved to be likewise the center of the most productive area of this vast chute of ore. Hecla shaft No. 1 adjoins it to the south (for the two companies were distinct until amalgamated in 1872). Within the Calumet lines there have been sunk five shafts, from 1 to 5, numbered from south to north, and within the Hecla and South Hecla lines twelve shafts, numbered from north to south. The disastrous fires of late years crippled the deep central shafts and shut off temporarily all access to the rich ores of the central zone, but previous to the fire the 700 foot level had been run south to the limit of the Calumet and Hecla property, and had traversed a second chimney of ore in the southern part of the South Hecla, known as the Black Hills section of the mine. With extraordinary energy this almost unexplored territory was opened soon after the first fire occurred, and so rapidly was the work of development prosecuted that, although between the years 1886 and 1887 there was a diminution of product from 22,553 to 20,543 tons of copper, this was due, not to a contraction in the tonnage stamped, but to a decline in the richness of the ore from 4·22 per cent. to 3·52 per cent. A large quantity of lean ore from the Black Hills mine, which was necessarily mixed with the richer ores of the central chute, caused the falling off. The next year (1888) showed a still further decline to 3·28 per cent. of copper in the rock treated.

The deepest point reached by the Calumet and Hecla is the twenty-ninth level, which is 3,750 feet from the surface on the incline of the bed. As the dip is 37½°, it makes the vertical depth 2,280 feet. This depth corresponds with the fifth level of the Tamarack mine, but the bottom of No. 4, the deepest Calumet and Hecla shaft, is 4,000 feet north of the No. 1 Tamarack shaft. It is therefore assumed that the Tamarack is working on the dip of the South Hecla or Black Hills chimney, and not on the central body. The sinking of the Tamarack vertical shaft to a depth of 2,270 feet on the chance of striking the Calumet conglomerate was regarded as a piece of great audacity in mining, for when it was begun in 1882 the lower drifts of the Calumet and Hecla were far above the level at which the vertical Tamarack shaft was expected to pierce the lode. But ere the goal had been reached, in 1885, the Calumet's deepest workings were approaching the same level; so that it became a foregone conclusion that the Tamarack hopes would be realized. To-day, the Calumet and Hecla has nearly re-equipped the burnt-out portion of its mine; it has also opened up a virtually new mine in the South Hecla; it has nearly reached its fortieth level, or a depth of 4,000 feet by its inclined shaft No. 4, and it is sinking a vertical shaft—the Whiting—which in less than two years will touch the central chute of ore at the vertical depth of 3,400 feet, or on the sixtieth level. Meanwhile, the Tamarack is sinking a third and a fourth shaft, which should both intersect the central chute of the conglomerate at a depth of about 5,000 feet, and Tamarack Junior, a company affiliated in ownership with the Tamarack, is sinking to the north of both the Calumet and Hecla and the Tamarack ground, in the hope of finding good ore below the Centennial property, a hope stimulated by the recent success of that latter company in striking remunerative ground to the north of its older workings. Within this limited range of three miles, besides the twenty-five inclined shafts, of which eight are deeper than 3,000 feet, there are sunk, or being sunk, seven vertical shafts, the shallowest of which is 2,270 feet and the deepest of which will be 5,000 feet. By the end of this year, the Calumet and Hecla will be daily extracting from the limited area 3,000 tons of ore and the Tamarack 1,000 tons; but these quantities, great as they are, could certainly be more than doubled within a few years, if it should be the policy of these companies to increase their production. And their neighbors, the Osceola, Centennial, Kearsarge and Tamarack Junior, will contribute in no small degree to swell the grand total. During the next generation, these nine square miles will probably produce more copper than any other equal area on the earth's crust. It is not within the scope of my present purpose to describe the methods of mining or of concentrating and smelting the ore; suffice it to say that the ore, though in some cases so very lean, is readily concentrated by automatic means into a product carrying from 30 to 90 per cent. of metallic copper, and that this concentrate is smelted and refined at one fusion. Until lately, the smelting was done for the mining companies by a separate smelting company, under contract, at so much per ton of copper. Now, the Calumet and Hecla company has its own smelting plant, and as one consequence, it reduces the loss of copper in its tailings by making concentrates of a lower grade.

ARIZONA.

Over 90 per cent. of all Arizona copper is derived from oxidized ores, which are found in the southern and middle sections of the Territory. Nature has reduced the copper in the Keweenaw rocks of Michigan to metal. In southern Arizona she has assisted the metallurgist by effecting a partial alteration of the ores to oxides and carbonates. In both cases the action has been attended with the elimination of certain elements injurious to copper, which are almost invariably associated with the sulphureted ores of the metal, and are difficult to extract by the usual smelting methods. Hence, copper made from native lake ore ranks highest in quality in the markets of the world, and that made from the oxidized ores of Arizona holds an intermediate place between lake copper and the metal made by the ordinary methods from sulphureted ores. It can be drawn and rolled, and stamped into intricate shapes, like lake copper, but it lacks the high electrical conductivity of that exceptionally valuable metal. It possesses the qualities of the copper from the Burra Burra and Moonta mines of south Australia, which is likewise the product of oxidized ores. This ore is smelted in water-jacketed cupola furnaces, by a single fusion, into bars of 96 per cent. standard, which are sold by the pound under conditions similar to those which govern the sale of Chili bars. With insignificant exceptions, all bar copper comes from the three districts of Clifton, Bisbee, and Globe. The principal mines in the Clifton district are owned by the Arizona Copper Company, a Scotch organization, and by the Detroit Copper Company. There are several groups of mines, some miles apart, the members of each group being related to one another, and forming a more or less continuous chain of deposits. The first property to be worked was the Longfellow. Though not itself the most productive mine at present, it lies in the strike of the most important series of ore masses. At Bisbee, and for miles around it, there are claims capable of producing more or less copper, but no other large ore deposit has been discovered than that which was opened as the Copper Queen mine in 1880. At Globe, the only large producer has been the old Globe mine, owned by the Old Dominion Copper Company.

The ore occurs in all three districts in, or adjacent to, carboniferous limestone, which has been chemically and mechanically influential in assisting the oxidation of the ore to a very considerable depth; for, through the crevices which intersect the limestone, and which have, in part, been the result of the ore decay itself, water has filtered down from the surface and decomposed the ore to a depth far below the line of decay of the adjacent feldspathic rocks, where these rocks are not themselves heavily charged with copper. In Bisbee, the ore beds appear to be confined to the limestone, but follow no regular order in their distribution. In Clifton and Globe, on the other hand, the ore bodies, though of irregular size and occurring at irregular intervals, are generally found in the plane

of contact between the limestone and granite, or the limestone and sandstone. Sometimes, however, and then over considerable areas, the granite and sandstone themselves are replaced by copper and associated ores. But even in these cases, the contiguous limestone has apparently played an essential part in the genesis of the oxidized ore. Sulphureted ores of copper are found in all of our extensively worked carbonate mines—sometimes in large masses, which for some cause, not always assignable, have escaped decay—occasionally even at a much higher level than that at which oxidized ores occur in the same mine. The average percentage of copper in the ore is difficult to determine, since unassorted ore is never delivered to the furnaces, while the grade to which it is selected is dependent in each district upon the cost of fuel and transportation. The furnace yield of Copper Queen wet ore is about 8 per cent., but almost as much very lean ore is stowed away in the stopes as is delivered to the furnace bins. The average ores of the other carbonate districts are probably richer and their furnace yield is notably higher. The deeper Queen ores consist essentially of ferric oxide associated with cuprous oxide and cupric carbonate, resulting from the oxidation of iron and copper pyrites. They are consequently basic. But sufficient silicious ore can be procured to supply the necessary acid flux for the furnace mixture. In the other districts, on the contrary, where the ore gangue consists largely of altered granites and sandstones, the silicious and aluminous constituents have been imperfectly eliminated, and barren limestone must be added to the furnace charge. But in none of the large producing mines does the average of the ore reach the high percentage promised to investors in the prospectuses of undeveloped Southwestern mines. It will be seen from this sketch that the Arizona ore beds are as strikingly irregular in their distribution as those of the lake are the reverse. The map of a lake mine is like a chess board, laid out with mathematical precision; that of the deep Arizona mines is more like a tangle of different colored threads. The only large copper mine in the northern half of the Territory is the Verde, in Yavapai county. There the copper occurs in lenticular masses embedded in crystalline schists, probably of Taconic age. Massive carbonates are found at the furnace, but at a shallow depth occur altered sulphurets or oxysulphurets which resemble those of the Southern States and of Butte. In this mine, as in all the copper-bearing veins in this section of the Territory, notable quantities of precious metals accompany the copper; but the gold and silver are irregularly distributed in the same vein and bear no uniformly definite proportion to the copper.

MONTANA.

Of far greater moment than the copper mines of Arizona are those of Butte, Montana. The principal mines have been opened on a lode which has proved to be continuous and productive for over three miles. The principal mines succeed one another from west to east as follows: Gagnon, Original, Parrott, Anaconda, St. Lawrence, Mountain View, Shannon, Colusa, and Hattie Harvey. The gangue of the vein is granitic and softened to a very considerable depth. It contains disseminated particles of ore, but most of the ore is derived from large embedded masses. One of these in the Anaconda is said to attain a width of 150 feet of solid mineral. Two, or perhaps three, parallel veins, or as many chains of ore masses in one very wide vein are traceable throughout its extent. Everywhere the copper carries silver in proportions varying from 2 ounces per unit of copper to less than ½ ounce per unit. The proportion of silver to copper is greater in the western section of the vein than in its central and eastern sections. The ores of the Gagnon mine are smelted into rich argentiferous matte at the Williams works, which ship their product to the Boston and Colorado Smelting Company, of Argo, Colorado. The Parrott ores contain about 60 ounces of silver to the ton of copper. The average silver contents of the Anaconda, Mountain View, and Colusa ores is less. Both the Chambers Syndicate and the Boston and Montana Company, however, make rich silver matte, but not from unmixed ores of the great lode. In following the lode from the Gagnon eastward, one ascends the western slope of a steep hill, traversing the Parrott and the Anaconda to the Mountain View, which covers the summit. In descending the eastern slope of the hill, one crosses the Shannon and the West and East Colusa. The latter is situated in the trough of a valley, and was formerly supposed to cover the eastern limit of the lode. But productive ground has recently been found far to the east of this point, extending the length of this vast lode a mile beyond its formerly supposed confines. The mines which lie at the extremities of the most productive section of the lode, viz., the Gagnon and Original on the west and the Colusa on the east, are likewise lowest in level. In them, the copper ore came to the surface, whereas in the Anaconda and the Mountain View, which crown the hill several hundred feet above the terminal mines, the surface ores to a depth of four hundred feet carry some silver but no notable quantity of copper. At about that depth, however, great bodies of oxysulphurets and erubescite were met with in the Anaconda, from which, in the early days, ores running fifty per cent. copper and over were mined by tens of thousands of tons. Subsequently, the Mountain View commenced to yield from about the same depth the rich decomposed ores which are now assisting the large product of the Boston and Montana Copper Company. The same oxysulphurets come to the surface, or are found near the surface, where the lode crops out in the valleys and on the flanks of the hill, but their depth and richness there are not as great as on the summit. Here it would seem as if the copper, leached out of the four hundred feet of depleted vein, had been concentrated in the underlying ore, and had thus produced a zone of secondary ore about two hundred feet deep, which contains, as might be expected, about thrice its normal copper contents. In the decuprified surface ore, silver was retained as an insoluble chloride when the soluble copper was removed. Therefore, we find that the proportion of silver to copper is less in the enriched copper zone, where an excess of copper is added to the normal silver contents, than in the unaltered ore beneath. Hence, the proportion of silver to copper increases with the depth. The Anaconda was bought as a silver mine, and preparations were being made to mill the ore when the shaft entered the copper. The experience of the Parrott and other mines confirms the theoretical anticipation that the lean unaltered ores carry a larger proportion of silver to copper than the overlying altered ores. No massive carbonates have been discovered, but the Gagnon and Parrott in their early days yielded small quantities of an earthy carbonate of copper, rich in silver. The altered ores of both the great lode and the smaller cross and parallel lodes consist mainly of a compact purple ore and of soft black ore with a bright metallic streak.

The actual copper yield of the Boston and Montana is given in the report of the company for the year ending June 30, 1890, at 9·36 per cent. This high percentage is the result of treating a very large proportion of the rich altered ore. Distributing the published yield of the Anaconda and the Chambers Syndicate mines over the number of tons said to have been transported from the mine to the smelting works—namely, 61,647,000 pounds of copper over 1,028,000,000 pounds of ore—we obtain, as the yield of the Anaconda, whose reserves of altered ore are not yet exhausted, 5·9 per cent. The ultimate yield of the deep copper ores of the great Butte lode and its subordinate veins will undoubtedly be lower still. Many small copper mines are being worked on the parallel veins, and on what appear to be spurs of the great lode. The operators are the Chambers Syndicate, a company closely connected with the Anaconda; the Boston and Montana Company, the Butte and Boston Company, and a number of individual owners. Some of the ore bodies of these subordinate lodes are large and their ores generally carry a profitable percentage of silver. In the aggregate they add largely to the present production of Butte, and considering the great length of ground which they represent, they insure for Butte a longer life than would be its lot if all the companies were making their extravagant drafts on the one great lode alone. Both Arizona and Montana have increased their production from year to year, but in very different proportions, as the following figures from *The Mineral Resources of the United States* show:

	Arizona. Lb.	Montana. Lb.
1882	17,984,415	9,058,284
1883	23,874,963	24,664,346
1884	26,734,945	40,612,783
1885	22,706 366	61,797,864
1886	15,657,035	57,611,621
1888	31,797,300	97,897,968
1889	31,600,000	104,200,000

CONCLUSION.

When we turn from a review of our present sources of production to the consideration of our ultimate resources, we wander at times from the domain of fact into the borderland of fancy. In the Appalachian chain from Vermont to Georgia there are embedded in the crystalline schists large masses of pyrites, some consisting of ordinary bisulphide of iron, but most of them of pyrrhotite, and all carrying more or less copper. In the north they are less conspicuous than in the south, where, in the absence of denudation, rock decay extends to a considerable depth, and the existence of the ore masses is indicated by an oxidized iron cap. In Vermont, as already mentioned, the Ely mine was an important producer between 1854 and 1882. In Maine, copper-bearing pyrites beds have been worked in two widely separated districts. New Hampshire has always produced a little copper. The Ore Knob mine in North Carolina yielded largely between 1873 and 1882. In Tennessee, the Ducktown mines produced annually more copper than any single Lake mine between 1852 and the advent of the Calumet and Hecla in 1866. Like all sulphuret mines, they became poorer as depth was attained. The Tallapoosa mine, in Georgia, was worked for several years, shipping its pyrites to phosphate works in Atlanta, Ga., where the copper was extracted from the cinder in the wet way. The Stone Hill mine in Alabama yielded a much higher grade of copper ore. There are very large masses of pyrrhotite in Carroll county, Virginia, which, despite its inferior sulphur contents, will sooner or later be used for acid making, and then made to yield up their very small percentage of copper. Considerable quantities of bisulphide of iron are mined near Charlemont, Mass., and in Louisa county, Va., but neither deposit carries any appreciable amount of copper. The Liberty and other mines in Maryland, as well as the copper-bearing slates and sandstones of Pennsylvania and New Jersey, are lying idle. At the present moment, therefore, the Atlantic States yield virtually no copper, and there is no reason to suppose that they will ever become large producers, inasmuch as they contain no bodies of pyrites comparable in size or in composition to even the smaller Iberian ore masses.

Turning to the Lake region, the case is very different. The larger of the existing mines will, doubtlessly, extend their capacity for production, and new mines will probably be more rapidly opened than the old ones will decay. There is only one mine in the country whose actual contents can even be guessed at. I refer, of course, to the Calumet and Hecla. Its ground has been explored laterally almost to its limits, and by its deepest workings, as well as by the exploration of the Tamarack Company, the value of its principal block of ground on the dip has been determined. Of course, there may be large tracts of unproductive vein within the area thus partially explored, which may, to some extent, impugn Mr. Agassiz's assumption that there exists within the Calumet and Hecla territory sufficient copper to last for forty years at twice the present rate of production. At what rate the administration may see fit to extract that definite quantity depends simply on the use which they wish to make of money, and of the appliances which money can furnish for extracting, transporting and refining their ores. The Tamarack has no means of ascertaining to what depth this same rich chute extends, but it is reasonable to assume that the depth of the ore bodies included in the Keweenaw rocks bears some relation to their length, and is therefore not illimitable. Outside of the Calumet and Hecla ore chute, the Quincy is the only mine whose ore is rich enough to sensibly affect future production in case the administration should deem it wise to increase the capacity of its new mill. But the Keweenaw rocks extend beyond Michigan through the northwestern part of Wisconsin into Minnesota, where I have seen them carrying small quantities of metallic copper, associated, strange to say, with sulphides of iron and copper. Metallic copper has been mined, though unprofitably, in Douglass county, Wisconsin, and salable quantities of copper have been found as float in the drift in Wisconsin. But the outcrop of the Keweenaw rocks, both in Wisconsin and Minnesota, is generally so heavily covered with forest and swamp that the discovery of copper in those regions will obviously be slow. In Michigan itself there is an almost boundless area of very lean amygdaloid and conglomerate rock, which will yield about one-half per cent. of copper, and will, therefore, attract mining only when a high range of prices is assured, for the starting of a lake mine, and the erection of the plant necessary to the economical treatment of the ore, is a costly enterprise. Thus we may count on a gradual but considerable increase of copper from the larger existing lake mines. It is also reasonable to suppose that new mines will be opened, and that, if the price be tempting, abandoned mines will be revived. At present, the price of the metal determines the activity of most of the smaller mines. During the late depression the cost of production in many cases hovered dangerously near the figures at which copper was sold.

Beyond the lake, lies the West—a wide and but partially explored domain. Looking at the existing mines, it is hardly probable that those of Arizona will greatly extend their production, though in none is there any sign of exhaustion. They do not grow richer with growing depth, and it is safe to presume that when the oxidized ores, including the oxysulphurets, give place to unaltered sulphurets, the latter will be leaner than the superjacent layers. In Butte, the extensive surface ground owned by the Chambers Syndicate and the Boston and Montana, and Butte and Boston companies, probably covers undeveloped bodies of rich surface ores. When the ravages of the fire in the Anaconda have been repaired, she will resume her former production; and the new work of the Boston and Montana Company at Great Falls, Missouri, will enable that company to increase its output. For a time, therefore, we may look for augmented production from Butte. But sooner or later even her output will decline by reason of the notable debasement which the deeper Butte ores undergo in common with the sulphuret of all copper veins. If a given standard of production is to be maintained, a corresponding expansion of plant will be required, and this in time will create unwieldy and unprofitable establishments. The resources of Butte are enormous, but they are drawn upon with lavish prodigality, and like everything else on the earth, even including copper mines, they are not inexhaustible. So much for the principal centers of active mining. As for the undeveloped riches of our West, it is to be borne in mind that although this wide expanse of territory has not been thoroughly explored, there are few districts which have not been superficially prospected. For forty years a large army of active and sanguine men has been marching back and forth over every obstacle, and in every season, traversing the Rocky Mountains from east to west and from north to south, in search of hidden treasure. That their search long ago was very thorough is being revealed ever more clearly by the rarity of the occasions on which fresh discoveries of large bodies of any metalliferous mineral are made at the present day. And copper is a metal whose ores betray their presence by such characteristic and brilliant colors that they are not easily overlooked, especially in a country whose naked mountain ranges are riven and deeply scored by the elements. Some new discoveries of large deposits are sure to be made, but they will be infrequent. It must be remembered that ten years have elapsed since the railroads gave access to Montana and Arizona, and led to the active development of the large mines in those sections that had already been discovered; and that despite the construction, in the interval, of other through lines in ramifying branches, no large deposit that was then unknown has been opened since. But while the copper world is not destined to be startled often by the apparition of an Anaconda mine, we have no cause to fear a dearth of copper even when the large mines now known have been exhausted. In every State and Territory of the Rocky Mountains we know of an abundance of low grade ores which will help us to maintain our supremacy in the ranks of producers when they become available by the growth of population, the cheapening of fuel and labor, and the application of still better metallurgical methods.

There extends through North-western Texas, Northern New Mexico, and Northern Arizona, a belt of Permian sandstone carrying nodules of rich ore and immense quantities of low grade ore, which at some future day will be utilized. The San Pedro mine in that section of New Mexico has figured at intervals as an important producer. In the Santa Rita district of Southern New Mexico large deposits of ore were once extensively worked. In the Clifton district, as, indeed, throughout great tracts of South-western Arizona, the very rocks are tinted green with copper; but the copper is associated with so much alumina and silica, and is so lean, that to-day it cannot be profitably treated. Nor are these the only undeveloped deposits of Arizona which simply await favorable conditions for exploitation. In the State of California large beds of low grade, sulphuret ores occur in Calaveras and Nevada counties, which besides promising a valuable yield of copper, will prove a most desirable auxiliary to California's future chemical industry. Passing to Nevada there are large deposits of low grade ores in Esmeralda county and ores of higher grade are reported to exist north of the line of the Central Pacific Railroad. Utah now contributes some copper, and Idaho will undoubtedly contribute much more than at present. She has copper deposits on the Lost river, and still more extensive deposits in the Seven Devils district on the Snake river, which, if nearer the railroad, would now be furnishing their quotum to the common stock. Oregon has unworked copper mines. The copper of Montana is not confined to Butte, nor are the States of Wyoming and Colorado barren. Taking into account the wide area over which we find copper, and the casualties of mining, which, if they generally bring misfortune, yet occasionally bless us with unexpected luck, we may allay all alarm of famine while dispelling any apprehension of a deluge. But we should understand that the great bulk of our undeveloped copper cannot be made available without a favorable price, and that only by drawing on these reserves can our

own and the world's requirements be met. It will require a greatly increased production, either from existing mines or new ones, to supply the world's ravenous demand for copper—a demand that springs from many new applications of the metal as well as from increased consumption for old ones.

The following table exhibits the rate of copper consumption in the United States since 1850:

Year.	Population.	Consumption in Tons of 2,000 lb.	Consumption per Head.
1850	22,191,876	6,710	0·550 lb.
1860	31,443,321	7,116	0·405 "
1870	38,558,371	12,342	0·603 "
1880	50,155,703	26,799	1·006 "
1889	61,000,000	34,800	2·736 "

The per capita decline between 1850 and 1860 is probably attributable in part to the introduction of iron in shipbuilding and the consequent abandonment of copper sheathing, and partly to the financial disturbance which reached its extreme depression toward the close of the decade. Electricity may be credited with creating an extraordinary demand within the last few years, but it had no part in raising the per capita consumption so steadily between 1860 and 1880. This was due to the growing wealth of the people, which stimulated the demand for fine metal work in architectural construction and decoration. A pro rata increase of consumption during the coming decade may not be maintained, though no good reason for a falling-off can be alleged. The present applications of electricity are few compared with its future uses, and although we may expect to see copper economized by the discovery of new methods for reducing the size of conductors, there is no probability that any other metal will supplant copper in the construction of dynamos or in the distribution of electrical energy. The necessity for sheathing iron vessels is most keenly felt now that speed is becoming the supreme consideration both in mercantile and naval marines, and we may therefore almost count upon the discovery of a successful method for effecting it. Such a discovery would naturally exert a potent influence on the balance between supply and demand. For ordinary household purposes copper will certainly hold its own, for even though aluminum should be produced as cheaply as copper, it would not displace bronze and brass, with their capacity for artistic treatment in color and form. If the growth of our population during the next ten years continues at the same rate as for the past decade, and the per capita increase of consumption is maintained, it will require in the year 1900 over 300,000 short tons of copper to satisfy the demands of this country alone, or about seventy-five per cent. of the world's present annual production.

The importance of the copper interests of the country as industrial enterprises is much greater than is ordinarily supposed. Without pretending that they rival the iron and steel industries as a national necessity, they bear no insignificant comparison with them. If we assume that the average of all copper ores treated carries 3½ per cent. of metal (and this is above rather than below the true average), and that our production of metallic copper in 1889 was 241,600,000 lb., this would represent the mining of 3,451,000 tons of copper ore, as against an annual production of 12,000,000 tons of iron ore, or about 28 per cent. The metallurgical treatment of copper, and more especially of the sulphureted ores, involves heavier costs in labor, fuel and material than the treatment of iron, and most of the subsequent manipulation of the metal in converting it into manufactured forms is more intricate. The comparative importance of the two metals in the national balance sheet, therefore, is to be estimated not so much by the respective weight of the finished products as by the relative amount of raw material and labor used in creating them.

STATISTICS FOR 1890.

The total production of copper in the United States in 1890 amounted to 101,861 long tons, of which 44,451 tons were contributed by the Lake Superior mines, or 38·2 per cent., of which the Calumet and Hecla mines were responsible for 26,539 tons. Divided into States and Territories, the result is Michigan (Lake Superior), 99,570,000 pounds; Arizona, 35,720,000 pounds; Montana, 111,010,000 pounds; New Mexico, 870,000 pounds; California, 2,140,000 pounds; Colorado, 6,760,000 pounds; Utah, 660,000 pounds; Wyoming, Nevada, Idaho, Middle States, New England States, Southern States, and lead refiners, 3,900,000 pounds; domestic product, 260,570,000 pounds; imported ores, 6,100,000 pounds; total product, 266,670,000 pounds.

The production of the various Lake Superior ores was as follows: Calumet and Hecla, 59,000,000 pounds; Quincy, 8,050,000 pounds; Osceola, 5,196,950 pounds; Franklin, 5,368,506 pounds; Allouez, 1,417,306 pounds; Atlantic, 3,644,403 pounds; Central, 1,366,011 pounds; Mass, 61,500 pounds; Copper Falls, 650,000 pounds; Huron, 1,758,748 pounds; Ridge, 21,569 pounds; National, 133,879 pounds: Knowlton, 20,000 pounds; Adventure, 15,485 pounds; Peninsula, 1,106,529 pounds; Tamarack, 10,091,064 pounds; Kearsarge, 1,616,556 pounds; Evergreen Bluff, 25,000 pounds; other mines, and tributers, 36,494 pounds; total, 99,570,000 pounds. The Arizona mines contributed to the total as follows: Copper Queen, 9,408,000 pounds; Holbrook & Cave, 8,047,310 pounds; Old Dominion, 7,782,190 pounds; Arizona Copper, 4,662,281 pounds; Detroit, 4,976,890 pounds; United Verde, 5,675,602 pounds; other mines 167,727 pounds; total, 35,720,000 pounds. The production of the Montana mines was: Anaconda, 64,046,812 pounds; Parrott, 9,000,000 pounds; Boston and Mont. and Clark's Colusa, 26,822,804 pounds; Butte Red. Wks., 3,300,000; Col. S. & M. 2,320,000; Butte & Boston, 5,357,733; all others, 162,661; total, 111,010,000.

SOAP FOR WOOL WASHING.

A GOOD soap for freeing wool of grease can best be prepared from olive and Cochin cocoanut oils. Seventeen hundred and sixty pounds of olive oil are boiled to a grain with caustic soda lye. After the soap has separated and the lye has been drawn off, 1,960 pounds of potash solution of 20° B. are added and allowed to boil a little. Now 440 pounds of Cochin oil are added, and when well taken up the same quantity of potash solution of 20° B. is gradually added as the soap can take it up. Then place in tinned forms of about 220 pounds capacity.

The entire process is easy, and the soap obtained is highly esteemed in washing wool, as the wool treated with it is open and has a good "feel," provided the consumer does not add any alkali to the soap solution with a view to making it act more rapidly, as is often done.

A cheap and less valuable article, such as is frequently used for cleaning ordinary wool, is also easy to prepare. Seventeen hundred and sixty pounds of elaine and 440 pounds of tallow are boiled to a grain, the precise method of boiling being immaterial provided one obtains a good firm grain. In another kettle a soda solution is prepared of 30° B. Now take 220 pounds of this soda solution, place it in a shallow kettle with 440 pounds of the grain soap, stir well and then add, with constant stirring, 220 pounds of dry soda.

In this way a thick paste is obtained, which is allowed to cool in the pan and is removed after 48 hours with a chisel. This is broken up into small pieces of the size of an egg, and packed in barrels for shipment.

A third process, which, however, is but seldom used in soap factories, is the following: Twenty-two pounds of caustic soda lye of 60° B. and 44 pounds of soda crystals are dissolved in 120 pounds of water and 44 pounds of elaine crutched into the solution. This mixture is adapted to wool washing and is generally prepared by the wool washer himself. The wool, however, becomes dry and brittle after its use.

Almost every establishment has its own "approved" formula, and every wool washer watches, argus-eyed, lest some one discovers his method of making "celebrated" soap. We can very cheerfully let these people retain their treasure, as a soap boiler would never allow himself to apply the name soap to such a mess.—*Der Seifenfabrikant.*

AUTOMATIC APPARATUS FOR PREVENTING BOILER INCRUSTATION.

MESSRS. FRYER & CO. have just undertaken the construction, in France, of a new apparatus designed for the realization of a process devised by Mr. Goodbody for preventing and separating the incrustations in steam boilers, while at the same time contributing to the lubrication of the parts of the engine in contact with steam.

For the application of this process, there is injected with the feed water a hydrocarburet, which may be the residuum of the distillation of petroleum, a natural product, or a subproduct of the distillation of schists containing hydrocarbureted oils.

The injector by means of which this result is obtained is represented in the accompanying engravings. Its operation is based in principle upon the difference in density between the carburet and the water put in presence in the reservoir, and which permits of transmitting to the boiler, drop by drop, the proper amount of disincrusting product. As this latter does not mix with the water, it is impossible to inject it into the boiler in a continuous manner, and this is why recourse is had to a special injector.

Fig. 1 shows the mounting of this apparatus beneath a horizontal feed pipe. At X there is a coupling pipe projecting in the interior, as shown in Fig. 3, in order to prevent the ingress into the injector of the impurities carried along by the water. If the feed pipe is vertical (Fig. 2), the apparatus is mounted in the same direction by means of a very short elbow, in order to prevent the agglomeration of the hydrocarbureted composition, which is semi-fluid.

When the boilers operate without feed water heater, the disincrusting apparatus is placed in front of the check valve and a little above it. If the contrary is the case, it is placed in front of the feed water heater, as shown in Fig. 4, so that the effects of the disincrustation make themselves felt in both apparatus. In these various applications, the method of using the injector remains the same. Before starting up, it is well to open all the valves and the plug, D, in order that the feed water may escape through the cock, C. After the hydrocarbureted composition has been introduced into the receptacle through the aperture, D, the cocks, A and B, are opened in order to allow of the entrance of the feed water in an exactly determined quantity. This drives before it the same volume of the liquid hydrocarburet, which floats on the surface and afterward enters the feed pipe through the glass tube. The discharge is regulated by the cock, B.

If the composition becomes too thick, or if the glass is dirty, the cocks, C and A, are opened for cleaning.

The product used for preventing boiler incrustation is, as we have stated, semi-fluid. That is why it is expedient to place the injector in the warmest place in the boiler room, so as to keep the product in a fluid state for use. Mixed with the feed water, it forms a thin pellicle on the internal surface of the pipes and boilers, and this prevents the calcareous salts in suspension from adhering to such surfaces in a solid form. The deposits are like mud, and are easily expelled by ordinary methods.

A single injector is capable of doing duty for several boilers supplied by the same feed pipes. Five hundred grammes of the hydrocarbureted product suffice in ten hours for a 100 horse power boiler, and this corresponds to about 5 drops per minute. This quantity naturally varies with the nature of the water employed. It will be found sufficient when the hydrocarburet floats upon the water in the tubes of the water gauges.

There is mentioned also as an advantage resulting from this injection a guarantee against priming in multitubular boilers and those of the locomotive type.

In the case of a new cylindrical boiler, it should be first coated with the hydrocarbureted product up to

FIG. 1. FIG. 2.

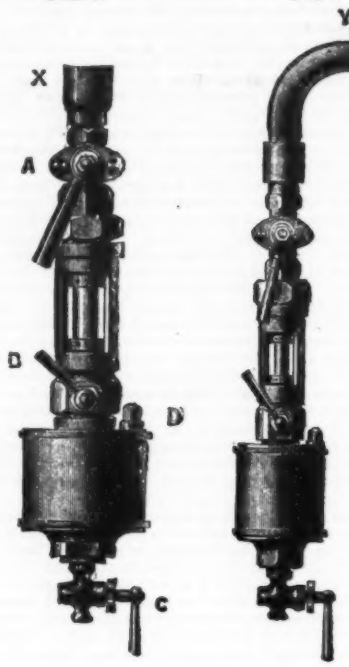
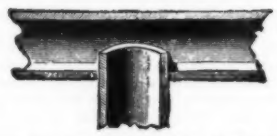


Fig. 3.



FIGS. 1, 2, AND 3.—DETAILS OF AN AUTOMATIC APPARATUS FOR PREVENTING BOILER INCRUSTATION.

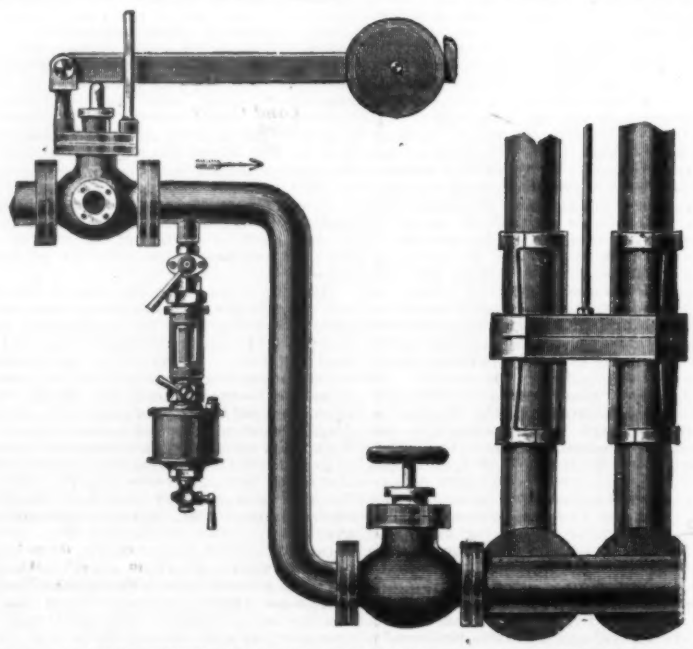


FIG. 4.—APPLICATION OF THE APPARATUS TO A BOILER PROVIDED WITH A FEED WATER HEATER.

the level of the water. For tubular boilers, it will suffice to introduce 500 grammes of it per 40 horse power, before filling them with water.

If it is a question of a boiler already incrusted, it should be washed, and afterward coated with the composition, and then, a fortnight later, after the boiler has been emptied, the incrustation can be easily removed. As the product is a lubricator, the cocks, distributing valves, etc., are kept in a good state, and operate with more ease.—*Revue Industrielle.*

[Continued from SUPPLEMENT, No. 812, page 12974.]

THE ADAPTATION OF STONEWARE TO CHEMICAL APPARATUS.*

By W. P. RIX.

WE have next to devote our attention to some of the—

E. *Difficulties of Manufacture*, as related to the form itself. The great object to be attained is *uniformity of tension* in drying, in firing, and in use. Though many other matters tend to assist this, equality of thickness is perhaps the most important for this result.

1. IN ARRANGING THE FORM OF THE VESSEL the following points should be noted:

(*a.*) *The shape should be such that if possible it has a suitable base to stand on in drying and firing.*

Thus the form shown at Figs. 7 or 8 should be

Fig. 7.

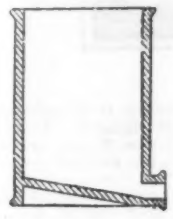


Fig. 8.

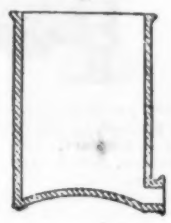


Fig. 9.

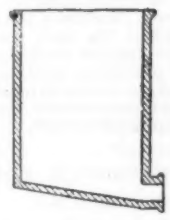


Fig. 10.

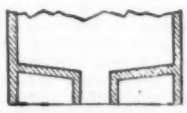
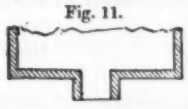


Fig. 11.



adopted, and not 9. In large vessels, say of 50 gal. and up, forms 10 and 11 would be almost impossible.

(*b.*) *The form should not tend to collapse.* Thus form Fig. 12, not 13, should be adopted.

Fig. 12.

Fig. 13.

(*c.*) *The positions of fittings should not be made to depend on accuracy of form;* thus the connections of Fig. 14 may become as 15 through sinking in firing.

Fig. 14.

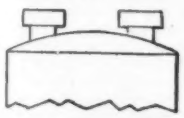
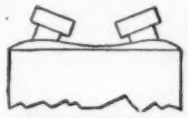


Fig. 15.



(*d*) *Nor upon freedom from torsion in ware*, as with a gauge glass socket. (See Fig. 16.) In this case the twist of the clay through making on the wheel causes the position of the sockets to shift from the perpendicular in the firing.

Fig. 16.

Fig. 17.

Fig. 18.

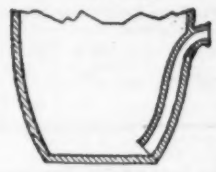
Fig. 19.

(*e*) *It must also be noted that forms thrown on wheel and cut are to be avoided;* thus Fig. 17 would be sure to twist (see Fig. 18), also still-head dip-arm in one piece would be very uncertain, as in Fig. 19.

(*f.*) Parts necessarily made by different methods have different shrinkages and cannot be struck without risk.

Thus, pipes stuck inside thrown vessels are to be avoided on account of both torsion and shrinkage, as in Fig. 20.

Fig. 20.



2. IN DRYING.—The following should be avoided:

(*a.*) *Unequal Thickness.*—The contraction takes place more rapidly in the thinner parts, and cracking results.

Thus, a thin copper may be suggested for economy of fuel and easy expansion, and if this is of large size additional thickness of flange might be asked for as adding to strength, but it is necessary to avoid the unequal contraction caused by this arrangement, and substitute 23 for 21.

Fig. 21.

Fig. 22.

(Also do not bolt through a flange, but outside it.)

(*b.*) *Unnecessary Width of Base.*—The large diameter of base should be avoided and reduced as much as possible, especially in large vessels, as the great weight prevents the mass from contracting at the bottom and cracks result in drying. Thus Fig. 23, not 24, should be adopted.

Fig. 23.

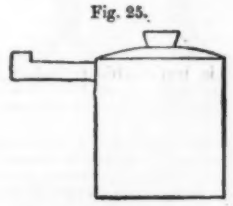
Fig. 24.

3. IN FIRING.—The following should be noticed:

(*a.*) *Projecting Parts* requiring support entail great risk.

The whole kiln when at full fire is in a state of semi-fusion, and the sinking of projecting parts can only be avoided by most careful adjustment of clay supports, the shrinkage of which must be precisely the same as that of the vessel, or cracking will ensue. (See Fig. 25.)

Fig. 25.



(*b.*) *In Pipes great length means great risk.*—The method of placing in the kiln may be either vertical or horizontal. In the former the play of fluctuating fire draughts direct on the ware causes warping. In the horizontal setting, allowance for free contraction of length is very difficult.

It would of course be possible to point out many other examples of undesirable form, but the principles of construction are perhaps already sufficiently indicated.

F. *Connections.*—The efficient connection of chemical apparatus is a matter of great importance to the chemical engineer. The means being greatly varied, it may be of interest to note the most important of these.

1. *Butt and Collar.*—The chief difficulty is in packing this joint, and it is most suitable for a run or cast joint, a small hole being left in the collar for the purpose. It is, however, very rigid, and a modification suitable for many purposes at moderate temperatures can be arranged by using an India rubber collar bound with wire.

Fig. 26.

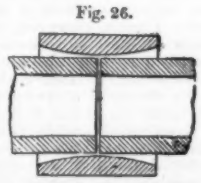
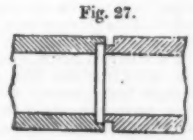


Fig. 27.



2. *Butt Socket.*—A very compact joint where space is confined, but the manufacture of the ware is troublesome, being liable to warpage and chipping of the outer wall of the socket, owing to the thinness of this part of the pipe on which it has to stand in drying and firing.

3*a*. *Butt Grooved.*—This is also open to the same objection of weakness in the socket butt. Besides this, in case of warping the grooves do not coincide and a bad joint results.

Fig. 28.

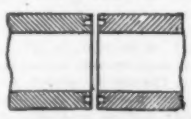
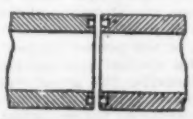


Fig. 29.



3*b*. *Butt Grooved Keyed.*—The groove may be countersunk, but this is even more difficult in manufacture, and further weakens the butt. By leaving two small holes in the outer edge of the pipe, a run joint of great strength and rigidity can be obtained.

4. *Spigot and Faucet* is undoubtedly the best joint for ordinary purposes, and easily connected by unskilled workmen.

Fig. 30.

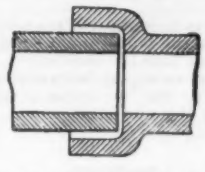
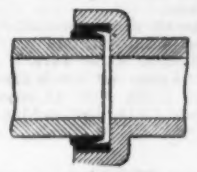


Fig. 31.



5. (Standford's patent) and 6 (Doulton's patent) are most useful modifications of the above for purposes which do not require a temperature above 100° F. The spigot and faucet have cast on and in them a lining of tar or asphalt composition by means of accurately fitting dies, which produce a true spherical joint. The pipes can therefore be fitted together perfectly tight without luting or cement, yet are able to be adjusted to slight curves of line and can be rapidly removed if necessary.

6. The faucet is cylindrical and the spigot spherical. The joint can thus be kept tight though the length of the run may spread slightly, which is not the case with No. 5.

Fig. 32.

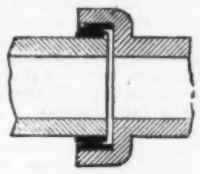
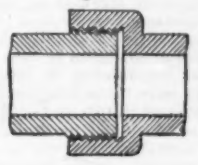


Fig. 33.



7. *Screwed Socket.*—This can only be successfully applied to connections of small diameter, say up to 1½ or 2 in. It should be noted that the allowance for warpage must be less than the depth of the thread, and this is not usually sufficient in larger sizes for so vitreous a material as stoneware. For this reason also coarse threads are desirable.

8. *Taper and Fillet* is only suitable for long pipes used vertically and of diameters under 9 in., as the joints cannot be made tight if the pipes are warped.

Fig. 34.

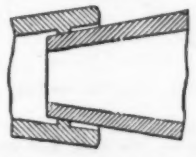
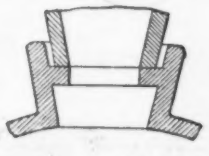


Fig. 35.



8*a*. *Butt Ground and Luted.*—This method is chiefly applied to jointing of stills and still heads.

Fig. 36.

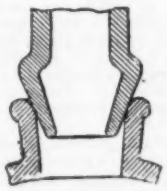
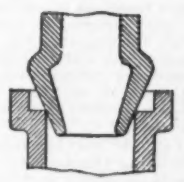


Fig. 37.



9. *Clay Lute.*—This is the usually accepted joint for receivers and stills, and for all arrangements where rapid disconnection is required, nothing can excel it. It is capable of easy adjustment to irregularity of level, and if suitable luting is used there is little danger of this falling into the vessel.

9*b*. *Socket Clay Lutes* are preferred by some, but on the whole there is more difficulty in keeping out the luting by this plan.

10. *Water Lute* sockets need little explanation. The greater the depth, however, the more risk of warped and ill-fitting connections.

Fig. 38.

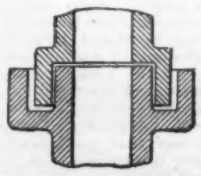
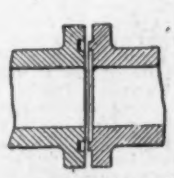


Fig. 39.



11. *Fillet and Groove* is a good serviceable joint and very tight under pressure with India rubber rings in the hollow. The flanges need not to be very strong and the bolts should pass through the clips outside and not through the flanges.

12. *Ground Flange and Groove.*—In this case the

Fig. 40.

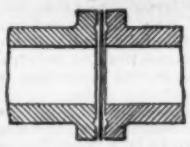
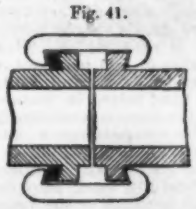


Fig. 41.



strain on the flange is greatly reduced, and India rubber flange can be placed between the two ground surfaces, which thus get a true bearing all over when

* A paper recently read before the Society of Chemical Industry; from the *Journal*.

screwed up. The India rubber expands sufficiently into the groove to prevent it from blowing out under pressure.

13. *Butt Ground Flanged.*—This patent joint (made by Messrs. Doulton) is very useful where rigidity is not an objection. The butt ends are ground true and the pipes held together with wooden wedges and iron clamps.

14—15. *Packed Gland Joint* (as in pumps). This needs no explanation, but in all cases the bolts should be carried outside the ware.

The greatest care is needed screwing up bolts with so rigid a material as stoneware, and no undue strain should be thrown suddenly on any one point.

Fig. 42.

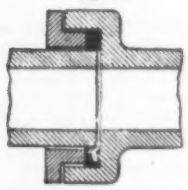
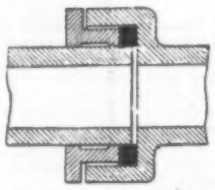
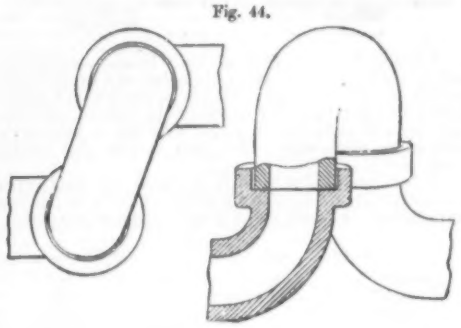


Fig. 43.



It should be noted that extreme accuracy in jointing, such as is sometimes attempted with ground surfaces and bolts, is liable to defeat its own purpose by its undue rigidity. Each joint being butt ground, no play in position or length is possible, and the whole apparatus, when screwed up, becomes rigid and incapable of adjustment to levels or even to the slight warping of pipes which is inevitable with all stoneware. A more serious objection is that no opportunity for expansion and contraction in length is possible, and it is therefore important in all such arrangements that *expansion joints* as shown at Fig. 44 should be introduced.

Fig. 44.



PLAN. ELEVATION WITH PART SECTION.

G. *Methods of Heating.*—The application of heat to stoneware vessels requires considerable care, and successful results in its use depend much on suitable arrangement.

The power of conduction in stoneware is very limited. It is needful, therefore, to distribute any sudden change of temperature over the whole surface of the vessel as much as possible. If this is not done, the heat directed on one portion causes this to expand before the transmission of the heat to other parts has taken place, and fracture is liable to ensue. For this reason any method which allows rapid circulation of the heat to all parts is to be preferred. Therefore a steam jacket or water bath is much better than a sand bath.

It is true that the latter allows of a higher temperature being transmitted to the vessel, but the heating is less uniform and cannot be so readily diffused through the sand.

In working with jacketed vessels much care is needed to protect the stoneware from the direct action of the inflowing heat, by a "baffling" piece.

In cases where the jointing of the vessel to the jacket is by means of a flange, it is necessary to remember that the additional thickness at this part prevents the equal expansion. Also that the part, if any, above the flange being generally exposed, and therefore colder, will not expand to the same extent in heating.

For these reasons the heat should be applied somewhat lower down in the jacket, so that the undue strain may not occur in the first application.

Some experiments were made several years ago, in which I assisted, under Coffey's patent, when stoneware vessels were heated to high temperatures by means of heavy paraffin oils circulating in closed jackets. The results were considered satisfactory and a temperature of 520° F. was obtained in the vessels without fracture. The oil itself was worked up to 800° F. on leaving the furnace. Considerable care, however, is required to obtain oil free from resins, which clog the pipes, and it is needless to say that very steady circulation has to be maintained to prevent the oil being overheated.

Another method of heating is by steam coils inserted in the vessel, the heat being transmitted through the coil to the liquid. If the nature of the operation will allow it, and a suitable material can be obtained for the coil, this plan is very satisfactory.

A more risky plan is the introduction of steam into the vessel itself. The concussion resulting from this arrangement is very liable to cause fracture, and every means should be taken to lessen the vibration, if it is resorted to. The vessel may be inclosed in a wooden or cast iron jacket and filled up with cement, concrete, loose sand, asphalt composition, or sulphur and sand mixed in suitable proportions according to the temperature required.

The temperature which it is possible to apply to stoneware is only limited by the fusibility of the material itself. Any temperature up to this point can be successfully used, provided it can be applied equally to all portions of the vessel at once; and also that the application is sufficiently gradual to allow of the penetration of the heat through the mass as well as its action over the surface. It is, however, usual at the ordinary thicknesses, and by the methods now in use, to recommend the employment of stoneware up to about 400° F. Beyond this point other bodies are to be preferred and special mixtures need to be introduced partaking more of the nature of fireclay in their composition.

TABLE D.—INTERNAL PRESSURE.

Terra Cotta.

760 Terra Cotta Glazed Pipes, 4 in. diam., ⅝ in. thick, 36 in. long. Tested to 100 lb. per sq. in.

Bursting pressure	20 lb.	30 lb.	40 lb.	50 lb.	60 lb.	70 lb.	80 lb.	90 lb.	95 lb.	*Note.*—Some pipes tested beyond burst at 120 lb.
Number of pipes broken	10	15	14	6	4	6	6	2	2	
Percentage, total	6·2	15·6	24·3	28·1	30·0	34·3	38·2	39·3	40·0	

TABLE E.—INTERNAL PRESSURE.

Stoneware.

Bore.	Thickness.	Length.	Pressure per Sq. In.	Remarks.
In.	In.	In	Lb.	
6	½	24	30	10 pipes stood.
6	½	24	35	1 pipe burst.
6	½	24	15	1 pipe burst.
9	½	24	30	10 pipes stood.
9	½	24	20	1 pipe burst.
12	1	24	30	10 pipes stood.
12	1	24	20	1 pipe burst.
12	1	24	30	1 pipe burst.
15	1½	24	25	1 pipe burst.
15	1½	24	30	1 pipe burst.
21	1½	24	30	3 pipes burst.

TABLE F.—EXTERNAL PRESSURE. (LONGITUDINAL.)

Stoneware.

No. 1.			No. 2.		
Diam.	Thickness.	Crushing Pressure.	Diam.	Thickness.	Crushing Pressure.
Inches.	Inches.	Cwt.	Inches.	Inches.	Cwt.
6	½	23½	6	½	44
6	½	18	6	½	50
6	½	25	6	½	52
9	½	22	9	½	47
9	½	20½	9	½	51
12	1	25½	9	½	52½
12	1	26½	12	1	64
12	1½	29½	12	1	64
15	1½	23½	12	1	64

No. 1.—Tested with 3-in. wide bearing at top and bottom throughout length.

No. 2.—Tested with one-half the circumference supported. Four segmental blocks, one above, one below, two at sides.

The capability, however, of rapid expansion and contraction without cracking is a quality not so easily obtained. It can only be secured:

1. By making the material very thin, so that there is not a great mass for the heat to penetrate.
2. By making the body coarser, so that the heat may penetrate more rapidly.
3. By the most careful annealing of the vessel during firing, so that the particles of the mass are not in any undue state of tension.
4. By using such materials as in themselves are liable to comparatively small contraction or expansion.

It is therefore only by the consideration of each chemical process according to its requirement that the best adjustment of the above methods can be arrived at. The coarser the body, the more porous the vessel. The thinner the vessel, the weaker for use and the more risk of warping and breakage in manufacture. The less the contraction of the material, the more friable the body of the vessel itself.

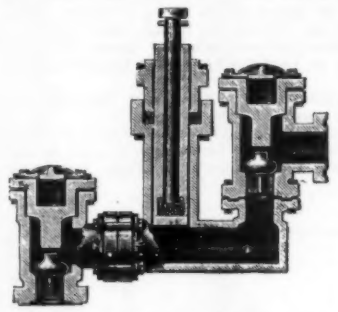
H. *Pressure and Resistance.*—I regret that the length of the present paper does not permit of my placing before you to-night any important facts in relation to this part of the subject. I hope, however, to have this opportunity on some future occasion. Meanwhile I wish to draw your attention to the following table, which gives the result of some few materials, although not directly relating to chemical stoneware.

It is, however, clear that the variation in the bodies used for chemical operations is so considerable that no definite information can be tabulated as to the strength, this being also partly dependent on the thickness and form of the vessels. (See Tables D., E., F.)

It is important to note that the thickness possible is limited, and cannot be increased proportionately with the size of the vessel. The pressure allowable, therefore, rapidly diminishes with increasing circumference. For this reason, if practicable, the strength of large vessels should be supplemented by the additional support of bands or jackets, and when these can be so arranged as to prevent the undue expansion of the vessel, and also equalize the strain, in this respect a very important result has been attained.

The comparison of the figures in Table F., Nos. 1 and 2, shows that even a partial support greatly increases the stability of the vessel.

J. *Special Apparatus.*—It has not been the intention of the present paper to enter on so wide a subject as the special application of various constructions or to describe the great variety of forms in which this material is manufactured. I may perhaps, however, be pardoned for bringing to your notice one such arrangement in evidence of the progress made, and which I think you will allow is a creditable instance of technical difficulties successfully overcome. I refer to the stoneware acid force pump. Some years ago I conceived the idea of producing pumps in stoneware, and after making such modifications as experience showed to be necessary, we have been able to turn out for some time past acid pumps up to 6 inch bore such as you see before you. The plungers are accurately ground, and the packing is of asbestos or India rubber, as may be most suitable. The valves are of stoneware, and the valve boxes are interchangeable, being also removable without detaching the pump.



I have also ventured to call your attention to the stoneware slabs for sectional acid tanks. By means of powerful and accurate machinery the edges of these slabs are ground to a true face, and can be used for lining tanks of other material or bolted together with care in a similar way to cast iron. For some purposes this system is very useful, and is the only method under which stoneware can be applied to the manufacture of vessels too large for producing in one piece. Much of the success of this plan, however, depends on the use of suitable cement and considerable care in the arrangements for bolting up the structure.

ELECTRIC DISCHARGE IN VACUUM TUBES.

By Prof. J. J. THOMSON, M.A., F.R.S.

THE phenomena of vacuum discharges were, he said, greatly simplified when their path was wholly gaseous, the complication of the dark space surrounding the negative electrode and the stratifications so commonly observed in ordinary vacuum tubes being absent. To produce discharges in tubes devoid of electrodes was, however, not easy to accomplish, for the only available means of producing an electromotive force in the discharge circuit was by electromagnetic induction. Ordinary methods of producing variable induction were valueless, and recourse was had to the oscillatory discharge of a Leyden jar, which combines the two essentials of a current whose maximum value is enormous and whose rapidity of alternation is very great.

The discharge circuits, which may take the shape of bulbs or of tubes bent in the form of coils, were placed in close proximity to glass tubes filled with mercury, which formed the path of the oscillatory discharge. The parts thus corresponded to the windings of the induction coil, the vacuum tubes being the secondary and the tubes filled with mercury the primary. In such an apparatus the Leyden jar need not be large, and neither primary nor secondary need have many turns, for this would increase the self-induction of the former and lengthen the discharge path in the latter. Increasing the self-induction of the primary reduces the E. M. F. induced in the secondary, while lengthening the secondary does not increase the E. M. F. per unit length. Two or three turns in each were found to be quite sufficient, and on discharging the Leyden jar between two highly polished knobs in the primary circuit a plain uniform band of light was seen to pass round the secondary. An exhausted bulb containing traces of oxygen was placed within a primary spiral of three turns, and on passing the jar discharge a circle of light was seen within the bulb in close proximity to the primary circuit, accompanied by a purplish glow which lasted for a second or more. On heating the bulb the duration of the glow was greatly diminished, and it could be instantly extinguished by the presence of an electromagnet. Another exhausted bulb surrounded by a primary spiral was contained in a bell jar, and when the pressure of air in the jar was about that of the atmosphere, the secondary discharge occurred in the bulb, as is ordinarily the case. On exhausting the jar, however, the luminous discharge grew fainter, and a point was reached at which no secondary discharge was visible. Further exhaustion of the jar caused the secondary discharge to appear outside the bulb. The fact of obtaining no luminous discharge either in the bulb or jar, the author could only explain on two suppositions, viz., that under the conditions then existing the specific inductive capacity of the gas was very great, or that a discharge could pass without being luminous. The author had also observed that the conductivity of a vacuum tube without electrode increased as the pressure diminished until a certain point was reached, and afterward diminished again, thus showing that the high resistance of a nearly perfect vacuum is in no way due to the presence of the electrodes.

One peculiarity of the discharges was their local nature, the rings of light being much more sharply defined than was to be expected. They were also found to be most easily produced when the chain of molecules in the discharge were all of the same kind. For example, a discharge could be easily sent through a tube many feet long, but the introduction of a small pellet of mercury in the tube stopped the discharge, although the conductivity of the mercury was much greater than that of the vacuum. In some cases ne

had noticed that a very fine wire placed within a tube on the side remote from the primary circuit would present a luminous discharge in that tube.

THE FARADAY CENTENARY.

IN his recent lecture at the Royal Institution Lord Rayleigh, according to *The Engineer*, said that the man whose name and work they were celebrating was identified in a remarkable degree with the history of that institution. If they could not take credit for his birth, in other respects they could hardly claim too much. During a connection of fifty-four years, Faraday found there his opportunity, and for a large part of the time his home. The simple story of his life must be known to most who heard him. Fired by contact with the genius of Davy, he volunteered his services in the laboratory of the institution. Davy, struck with the enthusiasm of the youth, gave him the desired opportunity, and, as had been said, secured in Faraday not the least of his discoveries. The early promise was indeed amply fulfilled, and for a long period of years by his discoveries in chemistry and electricity Faraday maintained the renown of the Royal Institution and the honor of England in the eye of the civilized world.

He should not attempt in the time at his disposal to trace in any detail the steps of that wonderful career. The task had already been performed by able hands. In their own "Proceedings" they had a vivid sketch from the pen of one whose absence that day was a matter of lively regret. Dr. Tyndall was a personal friend, had seen Faraday at work, had enjoyed opportunities of watching the action of his mind in the face of a new idea. All that he could aim at was to recall, in a fragmentary manner, some of Faraday's great achievements, and if possible to estimate the position they held in contemporary science. Whether they had regard to fundamental scientific import or to practical results, the first place must undoubtedly be assigned to the great discovery of the induction of electrical currents. He proposed first to show the experiment in something like its original form, and then to pass on to some variations, with illustrations from the behavior of a model whose mechanical properties were analogous. He was afraid that these elementary experiments would tax the patience of many who heard him; but it was one of the difficulties of his task that Faraday's discoveries were so fundamental as to have become familiar to all serious students of physics.

The lecturer then proceeded to show by means of an indicating galvanometer that an electrical current passing through one coil would produce momentary currents at the time of making and breaking the circuit in another coil near it, although the two coils were suspended in mid-air, and in no way connected. In December, 1824, Faraday tried to obtain an electrical current in a wire by means of a magnet, but not until August, 1831, that is to say, seven years later, did he succeed. On September 23, he wrote to his friend, R. Phillips: "I am busy just now again on electro-magnetism, and think I have got hold of a good thing, but can't say. It may be a weed instead of a fish that, after all my labor, I may at last pull up." It proved a very big fish indeed.

Lord Rayleigh continued that Clerk Maxwell had the first idea of making a mechanical model which would represent by analogy the induction of electrical currents. He then exhibited a gearing system of pulleys, in which the pulleys would work independently of each other, yet were all the time connected; and if one of them were made to work, the other would make a short motion whenever it stopped, and in the opposite direction to the primary motion, as is the case with induced currents. He added that the mechanical model in its action so resembled the action of induced currents analogically that their actions could be mathematically represented by the same equation. In another experiment, originating with Elihu Thomson, he took an electro-magnet in which the core consisted of bundles of iron wire, and in another coil of wire held over it while alternating currents were passing through the coil of the magnet below, sufficient electricity was generated by induction to cause an incandescent lamp to emit light. "It is perfectly clear of the magnet—there is no conjuring here," said the speaker. He showed that a copper plate interposed would act as a screen and prevent the result, but that a glass plate would not do so.

In another experiment an aluminum ring, A B, Fig. 1, was placed upon a ledge on the outside of the electro-magnet, D E, and when the current was sent through the coil of the latter, the aluminum ring shot up about 2 ft. in the air above the magnet, and was caught in its descent by the hand of the speaker.

Lord Rayleigh next exhibited an experiment devised by De la Rive, in which it was shown how water could not be visibly decomposed solely by a single Daniell's cell, but could be made to do so by the aid of induction. The method may be explained by means of Fig. 2, in which A is the cell, B the magnetic coil, and C the voltameter. While arranged as represented, water is not decomposed, but let the coil cell be first put on short circuit by the closing of the contact maker at E, and let the connection at E be broken, electrical force is then thrown, so to speak, upon the rest of the system, and the water in C is decomposed. The effect as projected upon the screen is shown in Fig. 4. There is something analogous to this in the case of an engine which by sheer pressure of steam might not be strong enough to force a punch through an iron plate, but which is enabled to do so by the aid of a fly wheel.

The lecturer continued that Faraday had always felt great uneasiness as to the soundness of contemporary views, and always experienced a fear of being misled by words. Having proved the complete identity of the electricity in lightning with that in the voltaic cell, he abandoned the term "pole" for "electrode," and considered the expression "electric fluid" a dangerous one. It was, indeed, a term which, as Maxwell observed, ought to be banished to the region of

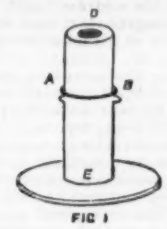


FIG. 1

newspaper paragraphs. Faraday reproved the identity of the electricity of lightning with the electricity of the voltaic cell, and tried numerous experiments to remove causes of doubt.

Lord Rayleigh next dealt with Faraday's discoveries in diamagnetism, and showed how the action of a magnet upon iron, nickel, and cobalt is different to its action upon bismuth and other metals.

Lord Rayleigh next illustrated the discovery which Faraday called the magnetization of a ray of light under the action of magnetic force; in other words, it was the rotation of the plane of polarization of light. The lecturer employed a tube filled with bisulphide of carbon, and with a coil of insulated copper wire surrounding it. Through this a disk of polarized light was thrown upon the screen, which became obscured when a current of electricity was passed through the coil. Sir Wm. Thomson was of opinion that some kind of rotation went on in the body submitted to the magnetizing force, but this only the future can show. The speaker made reference to Faraday's acoustical researches, but added that to enter into them would take him too far.

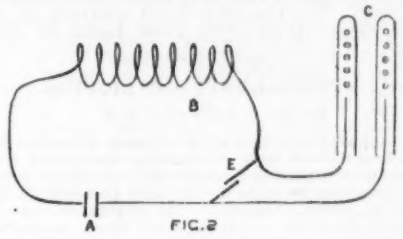
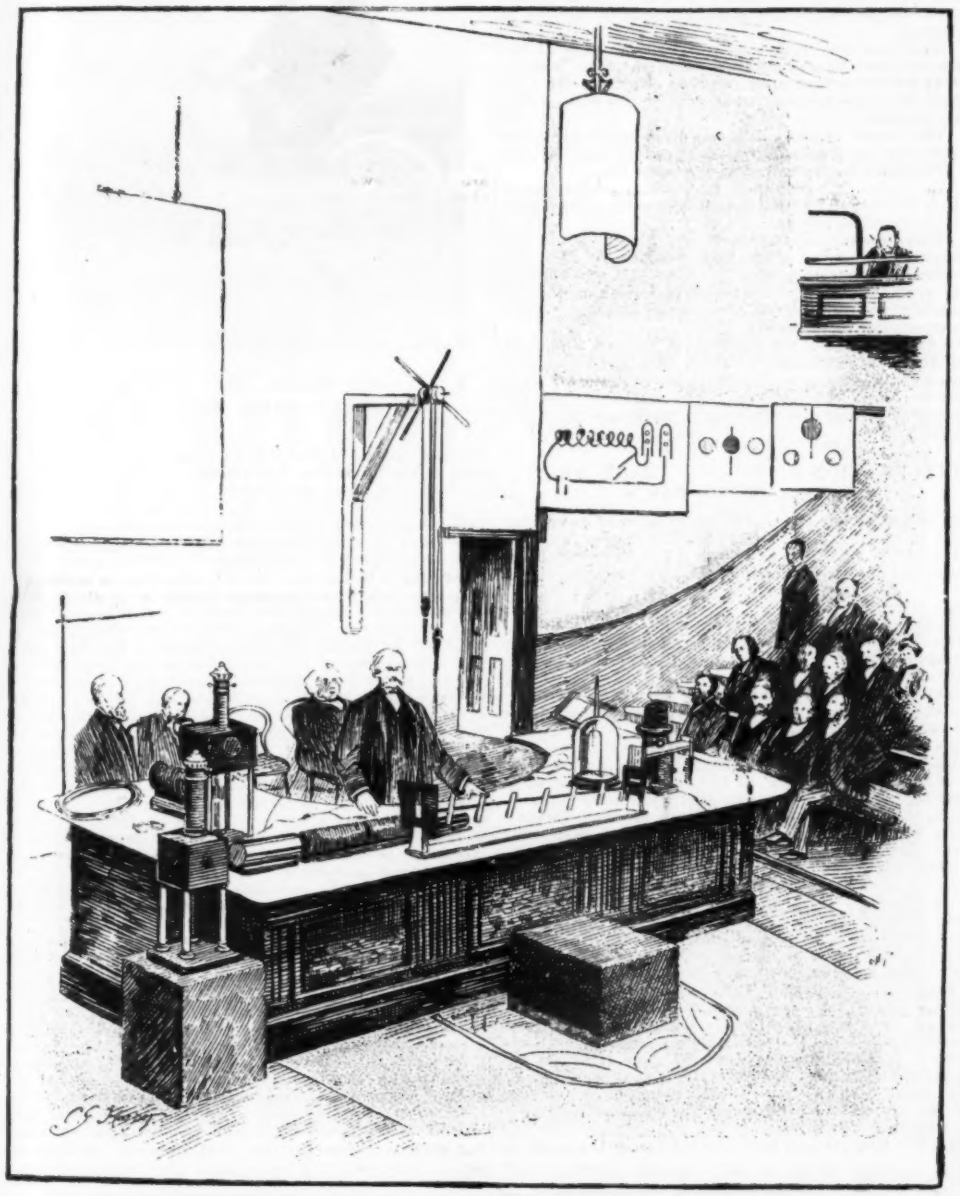


FIG. 2

Faraday once stated that if during a strong, steady wind the waves of the sea be observed off a flat shore by which the wind is not broken, waves are seen accurately parallel to the course of the wind. Two or three years ago the lecturer sought to observe this phenomenon at a French watering place at a time of low tide, and, after watching for half an hour or so, concluded that the waves or ridges were not to be seen, but a little later discovered that he had made a mistake, and that Faraday was in the right. The theoretical explanation of this is not yet known. Much more merit, said the speaker, appertains to a man who sees and notes a phenomenon for the first time than to an observer who sees it afterward, and he was doubtful whether any one but Faraday and himself had seen the waves just mentioned.

Lord Rayleigh concluded by saying that Faraday had also made a number of minor observations of great value, and he was reminded of one by a recent lamentable accident caused by the breaking of a paraffin lamp. Faraday had shown a method of holding the breath for a prolonged time by means of successive deep inspirations and expirations, which, if practiced, might have proved of saving worth on that sad occasion. The question had often been discussed, What effect on Faraday's career would have been produced if he had been subjected to a mathematical training?



THE LECTURE TABLE AT THE ROYAL INSTITUTION.

FIG. 4.

They must all feel that they would not have wished him to be other than he was. But if the question must be discussed, it would have to be admitted that by such a training he would have been placed in more thorough *rapport* with his scientific contemporaries; but mathematical training and mathematical capacity were different things, and it did not follow that Faraday had not a mathematical mind. In Professor Clerk Maxwell's opinion, Faraday had mathematical powers of a very high order, from which, if he had devoted himself to that science, valuable and fertile methods might by him have been discovered.

Sir W. Thomson, in moving a vote of thanks to Lord Rayleigh for his address, said that the Royal Institution was, during the last part of Faraday's life, and during the whole of his scientific career, his home. The splendid results of Faraday's labors contributed in no small degree to the scientific glory of the nineteenth century, and helped to make it one of the most prolific periods in the world's history. Faraday was throughout animated solely by the love of knowledge. He freely gave his discoveries to mankind and left it to others to turn them to practical and profitable account. Faraday pursued science pure and simple, for the sake of increasing natural knowledge. When Mr. Wylde showed him the first great machine for transforming mechanical power into electrical energy, Faraday remarked, "I gave the discovery to you a baby. You bring it back to me a giant."

VELOCITIES OF THE IONS.

By Mr. W. C. D. Whetham, B.A.

In studying electrolysis, the question as to whether there is any transference of solvent when a porous wall is absent presented itself to the author. The ordinary methods of testing for transference, such as by increase of pressure or by overflow, not being available when there was no diaphragm, the author used different colored solutions of the same salt, such as cobalt chloride in water and in alcohol, the former of which is red and the latter blue. By putting the solutions into a kind of U-shaped tube, any change in the position of the line of junction of the two liquids could be measured. Two aqueous solutions in which the anion was the same were also tried, one combination being cupric chloride and common salt, and in this case the line of demarkation traversed about seven inches in three hours. The results hitherto obtained by this method agreed fairly with those found by Kohlrausch.

COMPRESSIBILITY OF LIQUIDS.

By Mr. S. Skinner, M.A.

The apparatus consisted of a large spherical flask with a long narrow neck containing the liquid to be experimented upon, the lower part of which was in communication through a stop cock and flexible tube with an adjustable reservoir. By raising or lowering the latter, the flask could be easily filled or emptied, or the quantity of liquid adjusted. The flask was inclosed in a bell jar whose interior was in communication with a pump and barometer gauge. So sensitive was the arrangement that the compression of water produced by blowing into the jar caused the liquid to descend about one centimeter in the neck of the flask. This movement corresponded with a change of volume of about half a millionth. The coefficient of compressibility had been tested at different temperatures, and the results were not very different to those obtained by Tait and others. The influence of salts in solution in changing the compressibility had also been tested, and a great difference in this respect found between electrolytes and non-electrolytes.

AN ELECTROLYTIC PROCESS FOR SILVER AND COPPER ORES.

Wherever fuel is dear it is certain that the new electrolytic processes for the extraction of metals from their ores will attract considerable attention. In Spain and Chili, for instance, where much copper ore is to be found, most kinds of fuel are far from being cheap, and in such countries the electrolytic processes might well be taken up with advantage.

A recent issue of *Dingler's Polytechnisches Journal* contains a paper on the Höpfner process of extracting silver and copper from their respective ores by means of electrolysis.

Höpfner uses a bath which is separated into compartments by means of diaphragms; generally there are two such compartments, and in one are placed electrolytically insoluble anodes and in the other copper cathodes.

A double salt of cuprous chloride and a halogen salt circulates round the anodes, and a similar solution round the cathodes. On the copper spongy copper is deposited at a rate of 2·38 grammes per ampere hour, and this is double the quantity of metal deposited when a cupric salt is made use of.

If cuprous chloride were not present, then at the anode some free chlorine gas would form, and it would be necessary to have available an electromotive force of 1·8 volt. But in this arrangement the liberated chlorine at once unites with the cuprous chloride, converting it into cupric chloride, equivalent to 1 volt. Hence electrolysis can take place with an electromotive force of 0·8 volt, thus—

$$\text{E M.F.} = 1{\cdot}8 - 1{\cdot}0 = 0{\cdot}8.$$

Theoretically, the electrolysis commences with the consumption of 0·13 volt. This can be deduced by determining the heat of formation of cuprous and cupric chlorides.

As the liquid flows past the cathode it gradually parts with its copper, and is available for use again; but the copper is, of course, now present as cupric chloride instead of cuprous chloride, and the latter is made to leave the bath in a continuous stream. This solution is employed in an industrial way for extracting the metal from powdered copper and silver ores, special "leaching" vessels being employed.

If the ores are sulphides, then the following reaction takes place, viz.:

$$\text{Cu Cl}_2 + \text{Cu S} = \text{S} + \text{Cu}_2\text{Cl}_2$$

The solution of the cuprous chloride is regenerated, but it is twice as strong now as before, and so it is necessary to dilute it in order to bring it back to its normal condition of concentration; this is effected by mixing it with the waste liquors that come away from the cathodes.

The process, as will readily be seen, may be worked continuously, for the regenerated solution can be used over again as before.

This process would work admirably were it not for the influence of certain natural drawbacks. Sometimes there is present in the ores small quantities—perhaps only traces—of such substances as iron, arsenic, bismuth, antimony, etc., and these will pass into solution instead of the copper. The presence of iron is especially objectionable, since it very sensibly retards the solvent action of the copper salt upon the ore that is being treated.

These adventitious impurities must not be allowed to deposit along with the copper. Fortunately, however, it is by no means difficult to eliminate them, for they can be precipitated by means of copper oxide, and so easily separated off.

In working with silver and copper ores, the former metal, if it be present, is first deposited, and the resulting copper is obtained in a chemically pure condition.

The advantages which are claimed to pertain to the use of Höpfner's process are the following:

1. By electrolyzing cuprous chloride solution, the amount of copper deposited is twice as much as that which would be thrown down from a solution of sulphate of copper when the same intensity of current is employed.

2. Solutions free from iron can be made use of because the alkaline and alkaline earth chlorides possess a great solvent action upon cuprous chloride. In this respect also this process is superior to the copper sulphate process.

3. The most impure ores may be used, yet pure copper may be obtained, and from silver-bearing ores the silver may be deposited at the same time.

4. Forty-four kilogrammes of copper may be obtained by this method in twenty-four hours with an expenditure of one horse power.

5. When reckoning the work of the pumps and the mechanical agitation of the liquor at *one quarter*, and the electro-dynamic power at *three quarters*, of the total work necessary to do the operation, then with an expenditure of 30 kilogrammes of coal, 33 kilogrammes of copper may be obtained.

An examination of the figures just quoted will show that the results obtained by the Höpfner process of electrolyzing ores are higher than any which have hitherto been reached—so high, indeed, that the poorest ores may be profitably worked.—*Electrical Review.*

INTERNATIONAL BICYCLE RACE FROM BORDEAUX TO PARIS.

On the morrow of the international race from Bordeaux to Paris, concerning which the special journals and the daily press have furnished the public with the completest details, it is not without interest to reconsider an occurrence so important in the sport of bicycling.

Retracing in broad lines the various phases of the contest in which our English competitors so splendidly triumphed, we shall point out how, in a not far distant future, this momentary defeat of our fellow countrymen may give way to brilliant victories.

In the first place, let us in a few lines recapitulate the principal incidents of the race, in devoting ourselves more particularly to those from which we wish to draw a lesson. The start from Bordeaux took place on May 23, at 5 o'clock in the morning. Our large engraving (Fig. 3), made from an instantaneous photograph, shows us the grouping of the racers. Twenty-seven cyclists, placed in five rows, signed their road book. The following is an exact list, to which we add a twenty-eighth cyclist, Mr. Exben, who left Bordeaux seven minutes after the others: J. Renault (Paris), H. Gillot (Paris), Jiel-Lavat (Bordeaux), P. G. Mills (England), P. Rousset (Bordeaux), H. Tart (Orleans), Mr. Peres (Bordeaux), M. A. Holbein (England), S. F. Edge (England), P. C. Twentyman (England), Mr. Guillet (Blain), Mr. Exben (Bordeaux), A. Duphon (Bordeaux), G. Juzan (Bordeaux), H. Ulrich (Sevres), L. Gebleux, (Sevres), Mr. Bates (England), A. Desse (Royan), H. Jules (Paris), Mr. Coullibœuf (Vendome), Mr. Corre (Plestin-les-Greves), E. Pierre (Nancy), Mr. Bailly (Saint Amand), L. Masi (Switzerland), Mr. Issot (Royan), Mr. Huzelstein (Pamiers), J. Jouve (Bordeaux), Mr. Eyquem (Bordeaux). All of these racers were bicyclists, save one, Mr. Rousset, of Bordeaux, their dean, aged fifty-six, who rode a tricycle.

The five Englishmen took the lead from the start, so as to leave their competitors immediately behind them. The hours of passage were verified at various points of the route, the cyclists having to dismount in order to sign a register prepared for the purpose. They took advantage of this to refresh themselves in haste, and then started off again for the following registering station.

In the accompanying map (Fig. 2) our readers may very clearly see the principal points of the itinerary, with the hours of passage of Mr. Mills, the first to reach Paris. The details of the hours of passage of the various competitors would lead us too far; it is the incidents of the route that we wish to note here, in accompanying them with some reflections that they have suggested to us. The first of these occurred at the 17th mile, at Libourne. One of the best cyclists, Mr. Masi, of Switzerland, got a fall through the fault of a dog, and had his left arm badly bruised. Beyond Libourne, another dog crossed the road in front of the French cyclist Jiel-Laval, who, in endeavoring to steer clear of him, collided with Mr. Mills, whom he overthrew. Mills had his wrist and side skinned and his bicycle bent, but was still able, on his damaged machine, to make 12 miles, at the end of which a trainer furnished him with one that was in a good state. I have noted these two accidents, which were due to dogs, and which, seeing the speed of the cyclists, might have turned to tragedy, in order to point out the difference that exists in this respect between English and French dogs. In our country, horses and dogs are not yet sufficiently used to seeing bicycles, and many horses take fright at the sight of the rolling machine.

Fig. 1.—MR. MILLS, THE VICTOR IN THE BORDEAUX-PARIS BICYCLE RACE.

The duty of the cyclist in such a case is to dismount and wait until the animal has passed on or been quieted. As for dogs, a large number of them rush in front of the machine and bark at it, just as they do in the case of carriages; but they have no suspicion of the difference in speed between the two kinds of vehicle. The bicycle passes over their body and is upset and the rider gets a fall that is often very serious, while the dog gets off very lightly, especially if he is of a strong build. Contrary to what occurs with carriages, it is the one run over that receives the least harm; as for the rider, he may be killed instanter. So the French dog is the terror of cyclists, who are further fortunate when it is not the owner of the animal that excites the latter against them, as this has been too often done. "*Le chien, viola l'ennemi*," exclaims our confrere of the *Veloce-Sport*. "French dogs are devils!" writes Mr. Duncan, a cyclist correspondent, to an English journal. We are told by this writer that in England a complaint would be at once lodged against a dog that jumped upon a cyclist, and its owner would be compelled to pay a heavy fine. In France, the cyclist, in this respect, does not receive all the protection to which he is entitled, and complaints, save in cases of very serious accidents, are rarely listened to. So the discouraged cyclist contents himself with suspending a horsewhip near his hand, the protection offered by which is very often but illusory.

The machines employed were, for the most part, of the type intermediate between the light racing machine and the road machine, which is lighter, but not so strong. It was found with patriotic satisfaction that those that came from French houses were capable of contesting advantageously with the machines put forth by English manufactories. We must state that the pneumatic ruber tires, which seemed as if they were to revolutionize the construction of the bicycle and tricycle, have not performed what they apparently promised. They prevent jolting, and permit of using light wheels, while at the same time presenting a wide rolling surface on the ground; but, excellent as they are upon a well leveled track, they are difficult to use upon roads. The Bordeaux-Paris race showed that it is necessary to improve them greatly in order to render them practical. In fact, most of them split on the way, and put the machines with which they were provided out of use. Our skillful manufacturers will evidently set themselves to work to give us something stronger.

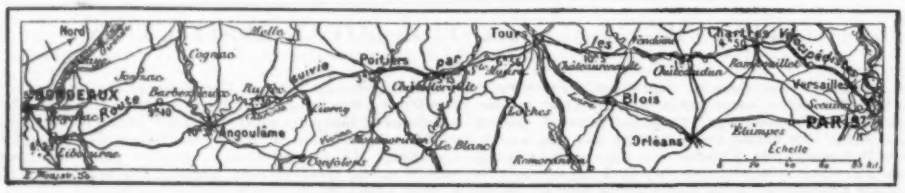


Fig. 2.—MAP OF THE ROUTE, GIVING MILLS' HOURS OF PASSING THE DIFFERENT LOCALITIES.

Let us now return to the race and follow the group of English cyclists, who reached Angouleme in the following order, Mills, Holbein, Edge, Bates, at thirty-

one minutes past eleven. On starting from Angouleme, Mills, thanks to his trainer, L. Stroud (well known in England), succeeded in distancing Holbein, the famous champion, who was considered as the future conqueror. Mills' machine had no brake; his feet were supported at their extremity by toe clips, metallic devices that keep the feet attached to the pedals. He was thus able, without letting go the pedals, to descend the very steep declivities situated between Angouleme and Ruffe. This bold maneuver secured his victory by giving him over his competitors an advance of thirty minutes, which he afterward increased. I shall pass over the details of the finish, which all the journals have described, and over the enthusiasm of the crowd and the ovations paid to the victor.

Our engraving (Fig. 1) represents him at the moment of his arrival, which occurred at the Maillot Gate, Paris, 7 h. 36 m. 25 s. He had therefore covered the 348 miles, the distance reckoned upon the Bordeaux road, in 26 h. 35 m. 57 s., beating Holbein by 1 h. 15 m. 50 s. and Edge and Bates by 3 h. 38 m. 52 s.

The following is the list of arrivals of the nineteen racers who reached Paris in the maximum delay of five hours fixed by the regulation of the race: (1) Mills (England) 7 h. 36 m. 25 s. Sunday morning, say in 26 h. 34 m. 57 s.; (2) Holbein (England) 8 h. 52 m. 15 s., in 27 h. 50 m. 37 s.; (3) Edge (England) 11 h. 15 m. 17 s., in 30 h. 13 m. 49 s.; (4) Bates (England) 11 h. 15 m. 25 s., in 30 h. 13 m. 57 s.; (5) Laval (Bordeaux) 1 h. 17 m. Sunday afternoon, say in 32 h. 15 m. 32 s.; (6) Coulibœuf (Vendome) 4 h. 19 m. 55 s., in 35 h. 18 m. 27 s.; (7) Guillet (Blain) 5 h. 45 m., in 36 h. 43 m. 32 s.; (8) Renaud (Paris) 9 h. 53 m., in 40 h. 51 m. 32 s.; (9) Corre (Cotes-du-Nord) 10 h. 35 m., in 41 h. 45 m. 32 s.; (10) Gillot (Paris), 10 h. 43 m., in 41 h. 41 m. 32 s.; (11) Gebleux (Sevres) 11 h. 4 m., in 42 h. 32 s.; (12) Bailly (Saint-Amand) 11 h. 4 m. 28 s., in 42 h. 1 m.; (13) Huzelstein (Pamiers) 4 h. 55 m. Monday morning, say in 47 h. 53 m. 32 s.; (14) Pierre (Nancy) 2 h. 51 m. 32 s. Monday afternoon, say in 57 h. 49 m.; (15) Rousset (Bordeaux) 7 h. 57 m. 32 s., in 62 h. 35 m.; (16) Issot (Royan) 9 h. 1 m. 32 s., in 63 h. 59 m.; (17) Desse (Royan) 9 h. 1 m. 33 s., in 64 hours; (18) Exben (Bordeaux) 2 h. 25 m. 28 s. Tuesday afternoon, say in 81 h. 24 m.; (19) Jouve (Bordeaux) 5 h. 1 m. 28 s., in 84 hours. And, now, what conclusion are we to draw from this magnificent tourney, which will form an epoch in the history of the velocipede? Do the English belong to a more vigorous race and one more resistant to fatigue than ours? Should we, before entering into a competition with them in athletic sports, improve ourselves as regards strength or skill? Their victory was genuine; on so long a stretch nothing can be attributed to accident. What, then, is the secret of their actual superiority? This is our answer: a long time before a race, the English champions submit themselves to a special training before facing the contests of the ring or road. All their efforts and all their thoughts tend toward a single end, that of progressively developing their force of resistance in order to increase their speed or the distance made. They put themselves into the hands of a trainer, who regulates their daily exercise, forbids excesses or fatigue of all kinds, weighs out their food, measures their drink, and, in a word, submits them to a most rigorous regimen. Our French champions, on the contrary, train themselves for the most part, our national character adapting itself with more difficulty to a life harder, not only than that of the soldier, but also than that of the prisoner or of one condemned to forced labor. Just as we recognize a tree by its fruit, just so we must acknowledge by their results the excellence of the English methods of training. Perhaps we might strip them of what they offer of the exaggerated or puerile in certain parts; but since their principles are excellent, let us not hesitate to adopt them.—*A. Good, in La Nature.*

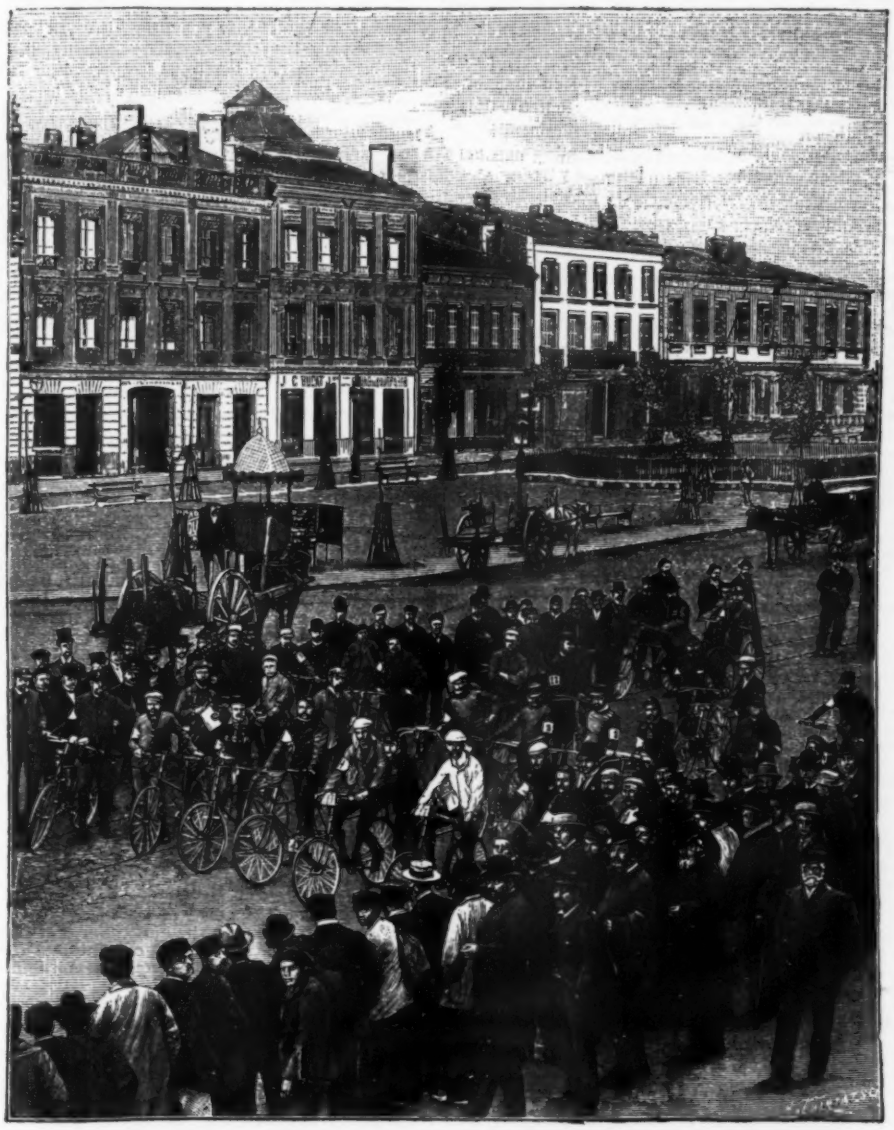


FIG. 3.—THE BORDEAUX-PARIS BICYCLE RACE—THE START FROM BORDEAUX.

THE ROYAL SOCIETY CONVERSAZIONE.

THE ladies' *soirée* of the Royal Society was held on the 17th of June in London, and was very numerously attended. The following, says *Nature*, were among the chief objects exhibited:

Finger prints as a means of identification, exhibited by Mr. Francis Galton, F. R. S. 1. Specimens showing the nature and character of the patterns that are formed by the papillary ridges on the bulbs of the fingers, as well as on the rest of the inner surfaces of the hands and feet. 2. Evidence of the persistence of the patterns in their essential details, however minute, from infancy to age. 3. Method of indexing a collection of finger prints so that a determination may be quickly arrived at, whether the duplicate of a given specimen is contained in it or not. 4. Process of making finger prints, exhibited in operation.

Registration of colors in numbers, and apparatus to show the greater sensitiveness of the eye to different colors, exhibited by Captain Abney, C. B., F. R. S., and General Festing, F. R. S. The registration consists in referring any mixed color to a single wave length and a percentage of white light. With the apparatus to show the greater sensitiveness to the eye of different colors, a comparison is made by placing two colors side by side, which are at ordinary intensity of equal luminosity, and by then diminishing the intensity of each equally.

An optical illusion, exhibited by Prof. Silvanus P. Thompson, F. R. S. On two rotating disks, A and B, are spiral patterns in black and white, which seem to move radially inward and outward respectively. Let the observer gaze fixedly for about one minute at the center of A, and then suddenly transfer his gaze to any object—say the face of a friend—he will see that object apparently enlarging from the middle outward. After similarly gazing for a minute at B, and then looking at any object, he will see it apparently diminishing.

Discharge without electrodes through gases, exhibited by Prof. J. J. Thomson, F. R. S. The discharge tube in these experiments is made to form the secondary of what is essentially an induction coil, and the discharge passes round a closed current in the gas. Experiments *a*, *b*, *c*, *d*, show various forms of the discharge in tubes and bulbs. *e* shows the residual glow produced when the discharge passes through oxygen. *f* shows the action of a magnetic field on the discharge; along the lines of force the discharge is facilitated, while at right angles to them it is retarded. When the magnetic field is "off," the discharge takes place in the bulb, and not in the tube; when the field is "on," in the tube, and not in the bulb. *g* illustrates the stoppage of the discharge when a gas electrically weaker than that in the discharge tube is placed in the neighborhood of the latter.

A nickel pendulum, illustrating the effect of heat upon the magnetic susceptibility of nickel, exhibited by Mr. Shelford Bidwell, F. R. S. Nickel, which at ordinary temperatures is a magnetic metal, becomes non-magnetizable at about 300° C. A copper disk, to which a projecting tongue of nickel is attached, hangs like the bob of a pendulum from a double thread, and is deflected to one side by a magnet which attracts the nickel tongue. The heat of a spirit lamp placed beneath the tongue quickly destroys the magnetic quality of the nickel, so that the magnet can no longer hold it; the bob accordingly falls back and performs an oscillation. On its return to the neighborhood of the magnet, however, the tongue has cooled sufficiently to be once more attracted, but after a momentary contact it is again released, and the process is repeated. Thus the bob can be kept swinging like the pendulum of a clock.

The meldometer, exhibited by Mr. J. Joly. This instrument is for determining the melting points of minute quantities of substances, by comparison with bodies of known melting point. The method consists in measuring the thermal expansion of a ribbon of pure platinum when a minute quantity of a substance, dusted on its surface (and observed through a microscope) is melting. The platinum is heated by a current, and the thermal value in degrees Centigrade of its expansion found by preliminary observations, using bodies of known melting point. The expansion of the ribbon is read by an electric contact method. The instrument shown reads a change of 2° C. Range up to 1600° C. about. Quartz may be melted on the meldometer, and most or all of the silicated minerals.

Fac-simile drawings of paintings from tombs at Beni Hasan, Upper Egypt, exhibited by Mr. Percy E. Newberry (of the Egypt Exploration Fund). A series of fac-simile drawings in color, executed by Mr. M. W. Blackden, of some of the most interesting paintings on the walls of the tombs of Ameni and Khnumhotep (XII. Dynasty, *circa* 2500 B. C.), at Beni Hasan, in Upper Egypt. These drawings are the property of the Egypt Exploration Fund.

Instrument for examining the strains in bent glass beams, exhibited by Prof. C. A. Carus-Wilson. There is a steel straining frame in which the beam to be examined is placed; this frame can be moved in any direction in its own plane between two Nicol prisms. The Nicol prisms can be rotated through any required angle. When the beam has been supported in any given manner, load is applied by a screw, and the action of the strained glass on the polarized light enables the precise state of strain all over the beam to be ascertained. The instrument has been used to determine the action of "surface loading," and to show to what extent this action affects the state of strain in beams supposed to obey the Bernouilli Eulerian theory of flexure.

Cup micrometer, an instrument for measuring the rate of growth of a plant, exhibited by Mr. Francis Darwin, F. R. S. A thread is attached to the upper end of the plant, passes over a pulley, and is fastened to a weight. The descent of the weight (which is a measure of the growth of the plant) is estimated by adjusting a micrometer screw carrying a small cup of oil, until a needle point on the weight touches the surface of the fluid. The method, a modification of that used by physicists to measure the rise or fall of a fluid surface, was designed by Mr. H. Darwin, of the Cambridge Scientific Instrument Company.

Electrical volatilization of metals, exhibited by Mr. W. Crookes, F. R. S.

Living animals from the aquarium of the Marine Biological Association at Plymouth, exhibited by the Marine Biological Association.

Art metal work, from the factories of Messrs. Tiffany & Co., in New York, exhibited by Messrs. Tiffany & Co. Representative articles in wrought metals; amalgamation of metals; enameling on silver and gold.

Photographs of living corals taken in Torres Straits, exhibited by Mr. W. Savile Kent.

Prof. J. Norman Lockyer, F. R. S., exhibited: 1. Photographs of a group of sun spots. A series of enlargements of a group of sun spots shown on the 12 inch sun pictures taken under the direction of Lieut. Colonel Strahan, at Dehra Dun, India, on December 16, 18, 19, 20, 21, 22, 23, 1887. The spots have been enlarged three times, and it will be seen that great changes took place during the period of visibility. 2. Photographs of the temples at Karnak and Edfou. These are enlargements from photographs taken in January, 1891, with reference to the orientation of the temples. The photographs show that, notwithstanding the elaborate details of the architecture, the principal axes of the temples were kept perfectly clear from one end to the other.

Prof. W. Roberts-Austen, C. B., F. R. S., exhibited a new, brilliantly colored alloy of gold and aluminum, and fac-similes of medals asserted to be of gold and of silver, transmuted from base metal by the aid of alchemy. One of the medals bears on its reverse the statement that it was struck in 1675, by J. J. Becher, in silver transmuted from lead.

Mr. Ludwig Mond, F. R. S., exhibited: 1. Nickel-carbon oxide. 2. Pure nickel extracted from nickel ores by means of carbonic oxide. 3. Articles of pure nickel deposited from nickel-carbon oxide, and goods plated with nickel by exposure to nickel-carbon oxide [$Ni(CO)_4$]. This unique chemical compound was obtained in 1890 by Mond, Langer and Quincke, by passing a current of carbonic oxide over finely divided metallic nickel at the ordinary temperature, and refrigerating the resulting gas. It is a colorless liquid of high refractory power, boiling at 43° C., and solidifying at 25° C., and is split up again into nickel and carbonic oxide on heating its vapor to 180° C. It is highly

poisonous; while according to Prof. McKendrick's researches it has, when injected subcutaneously in very small doses, a remarkable power of reducing the temperature of animals. The properties of this substance make it possible to volatilize nickel at a low temperature, and to extract it industrially in a perfectly pure state from all other substances with which it is found. Articles of pure nickel, and goods plated with pure nickel, are produced by exposing heated moulds or goods to nickel-carbon oxide vapor, or to a solution of this compound in suitable solvents.

Specimens of Japanese metal work, including *Ojimé*, or sliders, *Yanoné*, or arrowheads, and *Tsuba*, or sword guards, exhibited by Prof. A. H. Church, F. R. S.

Prof. A. Newton, F. R. S., exhibited a drawing, the first received in Europe, of *Notoryctes typhlops*, a new form of marsupial of mole-like habit, and structure accordingly, sent by Prof. E. C. Stirling, of the University of Adelaide, South Australia. The first specimen of this remarkable mammal, one of the most unexpected discoveries for many years, was sent from the interior of South Australia by Mr. A. Molineux to Prof. Stirling, of Adelaide, who contributed to *Nature* (vol. xxxviii., pp. 588, 589) such a notice of it as its imperfect condition admitted. He afterward obtained other examples, which are fully described in a memoir communicated to the Royal Society of Adelaide. "Four or five of the cervical vertebræ are fused, and there is a keeled sternum. An enormously thick and short first rib, which serves the purpose of buttressing the sternum in lieu of coracoids. Eyes mere pigment spots, underneath the skin and temporalis muscle. It has a remarkable habit of burrowing for long distances in the sand with great rapidity." These specimens were obtained about 1,500 miles north of Adelaide, but a telegram from Prof. Stirling, dated May 31, 1891, states that he has himself obtained others in the course of a journey, just completed, across the continent from Port Darwin.

Mr. Walter Gardiner, F. R. S., gave demonstrations of certain important phenomena associated with the absorption and the flow of the water taken up by plants: 1. Root pressure. Water present in the soil, and containing minute traces of nutritive salts, is absorbed by the root hairs so powerfully and in such quantities as to set up a considerable pressure in the interior of the plant. This "root pressure" may be demonstrated by attaching to the cut end of a stem a manometer containing mercury, or some colored fluid. Here a solution of nigrosine in water is employed. 2. The transpiration current. Among the more important factors which determine the flow and ascent of water from the root, upward, is the sucking force induced by the modified evaporation or transpiration of water from the general free surface of the leaves. During transpiration the water escapes as vapor, and the salts are retained for food. In this experiment the existence of a "transpiration current" is shown by allowing a cut branch to suck up milk, when the movement of the fat globules registers the flow of the liquid. 3. The amount of water absorbed by the root. This may be estimated by simple measurement, employing some such form of apparatus as that exhibited.

Engravings to "Travels among the Great Andes of the Equator," exhibited by Mr. Edward Whymper. These illustrations are selections from Mr. Edward Whymper's forthcoming work upon the Great Andes of the Equator (in which he gives accounts of the first ascents of Chimborazo, Cayambe, Antisanal, etc., etc.), and includes views on and about the equator at great elevations; incidents of travel; numerous examples of the new genera and species obtained on the journey; a fac-simile reproduction of the map of Don Pedro Maldonado (upon which existing maps of Ecuador are based), and the original route survey, and map of Chimborazo, made by the author. The work, with two hundred illustrations and four maps, will be published in the present year by Mr. John Murray.

Mr. W. Bateson exhibited: 1. models of double supernumerary legs and anteunæ in beetles; 2, mechanical model showing the usual symmetry of double supernumerary appendages in beetles. Supernumerary appendages in beetles nearly always spring as branches from a normal appendage, and are generally double, being made up of two limbs more or less compounded together. The two extra limbs are always *a complementary pair*, one being structurally a right limb, while the other is left. Commonly the symmetry of the parts is arranged as follows: *a*. The two extra limbs and the normal one stand in one plane, one of the extra limbs being nearer to the normal limb and one remoter from it. *b*. The nearer is in structure and position an image of the normal limb in a mirror at right angles to the plane in which the three limbs stand; and the remoter is an image of the nearer in another mirror beyond and parallel to the first. Thus the relations of the parts in their several positions may be represented by the mechanical model exhibited in which the extra legs, revolving round the normal leg, take attitudes proper to the positions which they occupy relatively to the normal leg.

Prof. A. C. Haddon exhibited the geographical distribution, and the progressive and retrogressive evolution of art and ornament in British New Guinea. The exhibit is designed to show that savage art can be studied as a branch of biology, and that it is only when so treated that it yields its most valuable results. Most savage and barbaric designs have only a very limited geographical range, and those which have a wide distribution can, in the majority of cases, be proved to be homoplastic and not homogenetic. The evolution of a particular pattern must be sought in the district in which it occurs, and its developmental history can only be safely attempted when a comparison is made of numerous objects from the same locality. The foregoing propositions are illustrated by means of specimens, rubbings, photographs and sketches of decorated objects from British New Guinea.

At intervals during the evening the Edison loud speaking telephone and Bell's receivers were connected with the performance of "The Gondoliers," at the Savoy Theater, London; the Prince's Theater, Birmingham; and with vocal and instrumental concert rooms at Liverpool and Birmingham.

Photographs of volcanic phenomena were exhibited by Dr. Tempest Anderson during the evening. These photographs of volcanic phenomena were taken last year during a visit to the Skapta Jokul, and other volcanic districts in Iceland. The eruption of the Skapta Jokul, in 1783, was one of the largest on record. A mass of lava, estimated to be equal in bulk to Mont Blanc, flowed out in two streams, each forty to fifty miles long. The actual craters situated in the desert interior of the island appear not to have been previously visited.

THE ELECTROMAGNET IN EYE SURGERY.

By SILVANUS P. THOMPSON, D.Sc., F.R.S.; and J. TATHAM THOMPSON, M.B., C.M.

FOR many years past, ophthalmic surgeons have used both steel magnets and electromagnets. Indeed, the use of the loadstone has been known for two centuries,* for the purpose of extracting from the eyeball chips of iron which have by accident lodged therein, as frequently happens in engineering workshops to fitters and metal turners. Later, in 1745, Dr. Milnes, in his "Observations of Medicine and Surgery," describes how he applied a loadstone to remove a piece of iron from the iris. Probably this was not strictly the case, as he says "immediately it jumped out." It is more likely that he meant that the fragment of iron was embedded in the cornea in front of the iris. According to Hirschberg,† Dr. Meyer, of Minden, was, in 1842, the first to use a magnet in extracting fragments of metal from the actual interior of the eyeball.

In the middle of this century cases of successful removal were recorded by Critchett,‡ Dixon, White, Cooper, and others. There seems to have been little advance until 1874, when Dr. McKeown, of Belfast, recorded in the *British Medical Journal* several successful cases treated by means of a permanent steel magnet tapered at each end to facilitate its introduction.

In 1880, Gruening, of New York, employed a permanent steel magnet composed of a number of "cylinders" (*sic*), united at each end and fitted at one extremity with a needle shaped pole.

The first use of the electromagnet in this connection is accredited to Hirschberg, of Berlin, in 1877.

In this country, Snell,‖ of Sheffield, has been the chief advocate of its use, and in his hands splendid results have been obtained. In the *British Medical Journal* for 1881 he describes his instrument and records the results of several operations. His experiments have steadily progressed since then, and in a recent number of the same *Journal* he brings up the number of his recorded cases to 77.

The thing needed for this special service is an electromagnet which can be fitted with polar appliances of various elongated forms which can be introduced into the wound in the eyeball to a sufficient distance to enable the particle of iron to be attracted and withdrawn. It is necessary at the same time that the electromagnet should not be too heavy to be conveniently held in the hand of the operating surgeon, and that it should be capable of being excited with current from a battery of moderate size, such as an oculist might be expected to be able to manage and maintain without having to call in a skilled electrician at every occasion of its use. It is obvious that, other things being equal, a magnet of considerable projective power is desirable; hence one with a long core, or with an iron expansion at the posterior end of its core, is preferable to a short one. Possibly in some cases the placing of a mass of iron behind the patient's head during the operation might aid the electromagnet to project its magnetic field to the desired depth. Various forms of magnets have been devised by various experimenters.

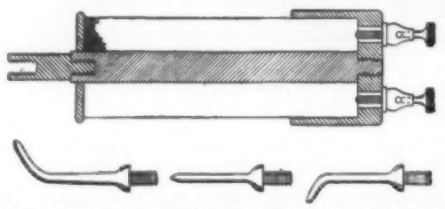
Snell's instrument, which may be quoted as the typical form commonly used by ophthalmic surgeons in this country, consists of a soft iron core surrounded by a coil of insulated copper wire inclosed in an ebonite case. At the one extremity are the terminals for the battery connections, and at the other the soft iron core is tapped to receive the variously shaped and sized needle poles. He recommends the use of a single quart bichromate cell to generate the current.

Hirschberg's instrument consists of a hollow cylindrical core with two curved pointed poles of different thickness for external and internal use.

Bradford, of Boston, devised an instrument almost identical with Snell's, and simultaneously with the latter. It is, however, a much heavier and more powerful agent.

McHardy, of King's College Hospital, used a very similar instrument, but of much reduced size and weight.

The latest form (see figure below) is that brought out



SPECIAL ELECTROMAGNET FOR EXTRACTING CHIPS OF IRON FROM THE EYEBALL.

by Tatham Thompson, of Cardiff, and is a further modification of Snell's instrument, but for the same weight and bulk additional power is claimed, as the magnetic circuit is perfected by means of a collar of iron continuous with the core projecting forward over the insulated coil toward the manipulative pole piece.

The core is tapped at its extremity to receive the differently shaped poles or an intermediate polar extension where deeper probing is required. The battery used with this consists of one or more quart bichromate "dip" cells. This instrument is shown in the illustration in its actual size, and its weight is only about five ounces.

The most frequent use of the instrument is in removing fragments of steel or iron from the surface or embedded in the coats of the eye; and by its use much disturbance and laceration of the delicate structures is avoided, which the older methods of cutting out or withdrawing by means of forceps, spuds, or curettes too often involved. Its most valued properties are, however, best demonstrated where it is used for the removal of foreign bodies which have penetrated the walls of the eye. It is not too much to say that in many cases it has been the only possible means of preserving sight.*

In the first place, it is of diagnostic value, for where a fragment, for instance, has perforated the cornea or anterior transparent part of the eye, it can be proved often whether it is steel or iron by observing whether it is acted on by the close approach of the instrument. If no movement is observed, and no peculiar sensation of dragging pain felt by the patient on the approach of the magnet, it may be due either to its not being a magnetizable metal or to its being gripped by the tissues, or encysted with inflammatory material thrown out by its irritating presence. If in this case a very lightly suspended needle be magnetized and held close to the eye, it may sometimes be found to dip toward the foreign body. If it should chance to be a steel fragment, this effect is greatly increased by holding the electromagnet close to the eye for a time, so as to magnetize the offending particle.

Further still, the instrument is at times of immense use in moving the fragment from one part of the eye where it is inaccessible, and dropping it in a more favorable position for subsequent removal. For instance, suppose the fragment of steel or iron has penetrated the cornea and lodged in the crystalline lens, it has happened in several cases that by applying the electromagnet to the cornea the metal has been attracted forward through the lens substance, across the aqueous humor contained in the outer chamber of the eye, and then dropped by opening the circuit on to the floor of the outer chamber; then a small opening being made at the most dependent part, the pole of the instrument introduced there, and the fragment readily removed.

In at least one recorded case a sharp pointed fragment, which had penetrated deep into the lens, has been seen to force its way forward through the lens substance and lens capsule, through the iris, and actually be drawn through the cornea, and so removed completely without involving any cutting operation whatever.

It is, however, in those cases where the foreign body has penetrated the posterior or vitreous chamber of the eye that the wonderful results obtained by the electromagnet are best seen. Where only the outer chamber or the lens is the seat of the mischief, other means may possibly succeed; but when a fragment has penetrated the vitreous chamber, we require an instrument not to go blindly searching round, disturbing the delicate structures and risking the escape of the semi-fluid contents, but one which will attract to itself the offending particle, and this is where the instrument which we are considering reaches its highest achievements.

Many successful cases have been recorded by Snell, Hirschberg, Lloyd Owen, McHardy, and others, of fragments of steel thus removed from eyes which otherwise must have inevitably been lost.

The most serious and desperate cases of all are where the metal has actually traversed the inner chamber of the eye and become embedded in the delicate retina and choroid lining the posterior wall. So far as can be ascertained, only three successful cases of removal from this position have been recorded. The first by Galezowski in 1882, where a fragment of iron had passed through cornea, iris, and lens, and was lodged in the retina. Its position was noted by means of the ophthalmoscope, an instrument employed by ophthalmologists for examining the interior of the eye. An incision was made in the sclerotic or white coat of the eye over the situation, and the fragment removed by means of the electromagnet. The second, recorded by Hirschberg in 1888. The third by Tatham Thompson, of Cardiff, in 1890. Some detailed account of this will illustrate the method of the procedure.

The patient was a blacksmith employed at one of the South Wales collieries; and on December 8, while "stamping" a new "pick," was struck on the left eye by a fragment of the new tool. The fragment struck him on the "sclerotic" or white of the eye, about a quarter of an inch from the margin of the cornea. He felt little pain at the time, but two days later dull pain supervened, and considerable irritation and dimness of vision, not only in the injured but in the sound eye.

He was sent to the Cardiff Infirmary on December 10. When examined there, a small wound was found at the point where the fragment had entered on the inner side, and on ophthalmoscopic examination, the piece of steel could be seen embedded in the retina at the upper and outer part. The track which it had made in traversing the vitreous chamber could also be distinguished by slight opacities in the humor. The uninjured eye showed distinct signs of sympathetic irritation. The next day the patient was put under the influence of ether, the wound of entrance slightly enlarged to allow the introduction of the pole of the electromagnet. This was passed across the vitreous chamber in as nearly as could be calculated the direction originally taken by the fragment. On withdrawing the first time nothing resulted, but at the second attempt the piece of steel came readily through the wound "in tow" of the pole. Only a very small bead of vitreous humor escaped, and the eye was dressed antiseptically and bandaged. At the end of 24 hours he could count fingers at 4 ft. distance, was quite free from pain and dread of light, and the dimness of the other eye had largely disappeared. The wound healed in three days, and the sight steadily improved till, on December 30, he could read moderately sized print. Examined by means of the ophthalmoscope, the scar formed in the retina at the point where the fragment had lodged could be distinctly made out, as well as some patches of hemorrhage caused either by injury from impact of the fragment or by injury of retinal vessels at the time of its removal.

On January 13, 1891, he could read small print; his central vision, in fact, was as good as ever, but his "field of vision" was limited slightly below—the limitation corresponding to the portion of retina injured by the foreign body.

The electro-magnet has been used also to some ex-

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* Fabricius Hildanus, *Opera observationum et curationum*, Frankfort, 1646. Of this rare work we have not seen a copy.

† Hirschberg, *Der Elektromagnet in der Heilkunde*, Leipsig, 1885.

‡ The *Lancet*, April, 1854, p. 368.

‖ Snell, "The Electro magnet and its Employment in Ophthalmic Surgery." London: Churchill & Co., 1882.

* In addition to references previously given, see Meilinger, *Ueber die Magnet Extractionen an der Basler ophthalmologischen Klinik* (Inaug. Dissert.), Basel, 1887.

tent in general surgery for the removal of needles from the soft tissues of the body or limbs.—*The Electrician.*

THE REACTIONS IN THE ALUMINUM ELECTROLYTIC PROCESS.

THE character of the reaction in the chief process by which pure aluminum is produced on a commercial scale in Europe and in this country has been the subject of discussion among metallurgists and chemists, but often opinions have been passed on it which prove the lack of thorough study and of practical investigation. The author of this article has had opportunity to see this process worked for a long space of time, and has experimented largely with the great facilities offered by the plant of the Cowles Company and of the Pittsburg Reduction Company, and therefore thinks he may be able to throw some light on this interesting question.

There are two interpretations of the reactions in the electrolytic bath. Heroult, for instance, whose French patent, No. 175,711, was issued in 1886, describes his process as the electrolysis of alumina dissolved in a bath of the double fluorides of aluminum and of a metal more electropositive than aluminum. Deville, about 37 years ago, clearly expressed the idea that the current decomposes the double fluoride of aluminum and of a metal more electropositive than aluminum, and that the oxide of aluminum which is fed into the bath by mixing it with the carbon of the anode serves for regeneration of the bath of fluorides. Still more distinctly Lossier, in a German patent of the year 1884, No. 31,989, expresses the idea that the fluoride is decomposed, and that the liberated fluorine, together with carbon, regenerates the fluoride bath. Lossier, in his specification, is even much ahead of the present process by ambitiously attempting to reduce silicious alumina by a very ingenious device. I quote from his specification: "The aluminum fluoride is decomposed under the influence of a current from the dynamo. The aluminum separates in a melted condition at the cathode, and being lighter than the liquid forming the bath, it remains on the surface of the same. The fluorine is liberated at the positive pole, and together with the carbon acts on the aluminum silicate coating and thus forms aluminum fluoride, which remains in the bath, while, on the other hand, silicon fluoride (a gaseous compound) and carbon oxide escape through the escape pipe." Heroult, in his French patent of April 23, 1886, and Hall, in his United States patent, 1889, express distinctly the idea that the oxide is reduced by direct action of the current, the double fluorides serving only as solvents; taking for example cryolite, the double fluoride of aluminum and sodium (Na_3 Al_2 Fl_6), we use it, dissolve alumina in it, and then pass the current through and effect the reduction of the metal; the aluminum being deposited at the negative electrode, and carbonic oxide appearing at the positive electrode, which latter consists in a carbon cylinder. The fact that carbonic oxide is generated in the operation, and further the fact that the fluorides waste only slightly, might at first sight corroborate the opinion expressed in the patent that alumina is directly decomposed and split up into aluminum and oxygen, the latter combining with the carbon of the positive electrode, and forming carbonic oxide.

Now let us examine more closely into the correctness of these two opposite theories. We have three compounds on which we can expect the current to act, namely, sodium fluoride, aluminum fluoride and aluminum oxide. If we were permitted to assume that, in the fused bath, one of these compounds was a non-conductor, and consequently a non-electrolyte, the answer to the question which compound was acted upon by the current would be much facilitated; as we have here, however, a perfectly liquid and homogeneous mass, and as the alumina is thoroughly dissolved, we cannot suppose the current to select on its path through the bath only one of three compounds, and leave the others untraversed. In order to more fully explain this, let us examine what a solution really is. First, let us take a simple example, the solution of common salt in water. What happens? When we dissolve common salt (Na Cl) in water, the elements of the dissolved compound simply exert their affinities for the elements of the solvent until an equilibrium is established; the sodium attracts the oxygen, and, as is well known, this affinity is strong, and the chlorine attracts the hydrogen of the water. A solution of the above character is then in reality a chemical combination of the solvent with the compound dissolved. For a second example take a case where the affinity of the elements of the compound to be dissolved for each other is overwhelmingly stronger than the affinities for the elements of the solvent. No solution takes place, and the mass is but a mechanical mixture, as in the instance of mud and water. Now for a third case where decomposition ensues. In the case of silver chloride, for instance, the affinity of silver for chlorine is so much greater than that for oxygen that the additional affinity of chlorine for hydrogen is not sufficient to effect solution; taking mercurous chloride or calomel, we find that it is insoluble in water, since the affinity of mercury for oxygen is very small as compared with its affinity for chlorine, and the affinity of the two atoms of chlorine for hydrogen not sufficient to effect solution. If, however, the same quantity of mercury is combined with a double quantity of chlorine, as is the case with mercuric chloride, then the attraction of the hydrogen in the water for chlorine is doubled and solution is effected. Cuprous and cupric chlorides form similar examples. It is evident from this explanation that the force by which elements are held together in a compound is diminished by dissolving the compound or fusing it with appropriate other compounds, a fact which is further illustrated by the observation that the electrical energy required to decompose a certain compound is considerably diminished if that compound is in a complex solution, or fused together with appropriate other compounds of greater stability.

If we examine, with this view of a solution, the Heroult bath, we see at once the complex relation which exists between the attractions of the various elements of the three compounds for each other. The sodium attracts the oxygen and also exerts its affinity for aluminum, since the formation of aluminum sodium alloy is accompanied by the evolution of a considerable amount of heat and takes place at a low temperature. There is also interaction between aluminum fluoride and aluminum oxide, resulting in the formation of an oxyfluoride of aluminum; thus the aluminum is completely dissolved. From the above it follows that the fused bath of cryolite and alumina conducts the current as a whole, and the question remains to be answered which of the three compounds present is dissociated by the action of the current. No doubt the least stable compound will be acted upon by the current, *i. e.*, that compound the elements of which are held together by the least force under the precise conditions of temperature, solution, etc., of the electrolytic bath. To determine this stability *a priori* according to definite laws is a task which at the present stage of chemical knowledge we cannot undertake. Thermochemistry can sometimes act as a guide, because the amount of heat evolved in the formation of a compound is in close relation to the force by which the elements of that compound are held together, and we can calculate from the amount of heat which is evolved in formation of a compound the electromotive force that is required for decomposing that definite quantity of a compound which is called its electro chemical equivalent. I make a remark here incidentally that the distinction made between chemically equivalent quantities and the electrochemically equivalent quantities is unjustified. Looking at the different quantities of iron which are liberated when the same current during the same time electrolyzes ferrous and ferric chloride, we conclude that three molecules of ferrous chloride are equivalent to two molecules of ferric chloride, and from a purely chemical standpoint we should say that one molecule of ferrous chloride is equivalent to one molecule of calcium chloride, while three molecules of calcium chloride are equivalent to two molecules of ferric chloride, from which it follows that one molecule of ferric chloride is chemically not equivalent to one molecule of ferrous chloride, but that rather, as is the case in electrolysis, three molecules of ferrous chloride are equivalent to two molecules of ferric chloride; we can therefore more simply express the relation of electromotive force and heat of combination by saying that the electromotive forces of compounds are to each other as the heats of combination evolved in the formation of equivalent quantities of these compounds.

In stating this law we must not forget, however, that temperature, pressure, etc., modify this force, and a single example will illustrate this fact. Compare, for instance, the heats of formation of equivalent quantities of sodium oxide and sodium chloride; we find that sodium oxide evolves about one-half as much heat in its formation as is evolved by two molecules of sodium chloride, yet sodium chloride dissociates into sodium and Cl at a temperature of 1,500° C., while sodium oxide (Na_2O) is practically infusible at any temperature except that of the electric arc. It is ever apparent that the force which holds the two elements in sodium chloride together must be weakened before the temperature of dissociation is reached, and the electromotive force to accomplish this dissociation must be very much smaller than we should infer from its heat of combination, and certainly much smaller than that required to dissociate any Na_2O. It is also evident that at a temperature of dissociation the electromotive force must be zero. Since we have no direct measure of the stability of the compounds in question under the conditions of the electrolytic bath, we have to look for another method of solving the question. This method consists in studying the chemical reactions of the substances at the temperature of the electrolytic bath, which I think is about 900° C. Viewing first sodium fluoride and aluminum fluoride, we know that at the temperature mentioned sodium fluoride is the most stable compound; that is to say, the affinity of fluorine for sodium is stronger than that of fluorine for aluminum, for sodium is capable of displacing aluminum in its fluoride, a reaction which occurs according to this equation: $6Na + Al_2F_6 = 6NaF + 2Al$. At a higher temperature sodium is not capable of effecting this displacement; in fact, it is well known that aluminum placed in fused cryolite has been dissolved, and this can only be explained by the reversion of the above reaction, namely, $6NaF + 2Al = Al_2F_6 + 6Na$.

In metallurgy such reversions of reactions are not infrequent: zinc oxide, for instance, at a certain temperature, can be reduced by carbon, the products being metallic zinc and carbonic oxide. At a higher temperature zinc vapor is capable of reducing carbonic oxide, the products being zinc oxide and carbon. Some chemists have tried to account for the absorption of aluminum by supposing the existence of a subfluoride of aluminum. Aluminum subcompounds have never been proved to exist, and from the position of aluminum in the tables representing the periodic law, the existence of such compounds is highly improbable. The passing off of sodium vapor in case pure cryolite is electrolyzed at too high a temperature can easily be observed; the sodium vapor burns then with its characteristic brilliant yellow flame. We are then permitted to assume that of the two compounds, sodium fluoride and aluminum fluoride, the current would decompose aluminum fluoride, in spite of the fact that there are indications that aluminum fluoride in its formation evolves more heat than equivalent quantities of sodium fluoride.

The question now remains to be answered, which is the most stable compound, aluminum oxide or aluminum fluoride? From a calculation made by me I should conclude that the heat of formation of aluminum fluoride for lower temperatures is greater than that of the oxide, but whether at the temperature of the electrolytic bath the stability of halogen salts is not very materially weakened is another question. The halogen salts, as a whole, are easily dissociated, so that we may suppose that at the temperature of 900° C. the affinity of fluorine for aluminum is considerably diminished, while, on the other hand, we know that metallic oxides, with exception of the noble metals, are extremely stable at very high temperatures.

The following facts will show how temperature affects the stability of aluminum fluoride. Aluminum fluoride is insoluble in liquid water, that is to say, the great affinity of aluminum for oxygen is not capable of weakening the strong union between fluorine and aluminum so as to effect a solution; nevertheless, we know that if we heat cryolite to such a temperature as to effect volatilization, which temperature is not much above that of the electrolytic bath, and then bring it in contact with vapor of water, reaction takes place, and aluminum oxide is formed according to the equation $Al_2F_6 + 3H_2O = Al_2O_3 + 6HF$; in this reaction, of course, the great attraction of hydrogen for fluorine plays its role; the probability is, then, that in our case aluminum fluoride more easily decomposes than the oxide. Another method for determining the strength of union of the oxide as compared to that of the fluoride would be to measure the resistance of either compound to the passage of the current. Unfortunately, aluminum oxide fuses at so high a temperature that accurate measurements are practically impossible. To determine the resistance of alumina when dissolved in the electrolytic bath is evidently an impossibility, for the reason that the fluorides and the oxide together as a whole conduct the current; yet measurements were made. The resistance of the bath with the oxide was first measured, then the resistance was measured of the bath containing no alumina. The resistance in the first case was considerably smaller than in the case of the bath free from alumina.

It does not require great sagacity to perceive at once all the errors of such measurements. It is one of the elementary principles in the art of electrolysis that a complex solution conducts the current incomparably better than a single compound, *i. e.*, we can decompose a certain compound by using a current of a certain electromotive force, and we can decompose the same compound by using only one-half of that electromotive force if we dissolve certain other salts in the same solution. This fact is in close connection with our theory of a solution, namely, that the force by which the elements in a compound are held together is diminished by the attraction of these elements for the elements of other compounds in the solution. In the case of our electrolytic bath we must ascribe the difference of electromotive force in the two cases partly to the fact that the solution of alumina increases the conductivity of the bath; but there are more potent factors that fully explain the rise of resistance of the fluoride bath when it is free from alumina. Let us suppose, for the sake of argument, the stability of alumina and of the fluorides under the conditions of the electrolytic bath to be the same, then neglecting also the solution effects of alumina on the conductivity; then in case the alumina be decomposed, the oxygen of the alumina will combine with the carbon and produce heat energy, which is imparted to the bath and helps to keep the same in fusion, and thus that part of electrical energy which would be required to furnish this heat by converting electrical into heat energy is saved, and consequently less voltage is required to decompose the alumina and overcome the resistance of the bath and keeping the same in fusion than if the bath were free from alumina and the current decomposed only the fluoride of aluminum. That this heat furnished by the combustion of carbon is quite considerable appears from the following calculation. Supposing two pounds of aluminum be reduced in one hour by the electric current, then 1¾ pounds of oxygen are liberated. This amount of oxygen would combine with the carbon of the anode to form carbonic acid. We know, however, that one kilogramme of oxygen when it combines with carbon evolves 6,000 calories of heat; hence 1¾ pounds would evolve about 5,000 calories, an amount of heat sufficient to raise the temperature of 1,000 pounds of water one degree Centigrade.

From this follows that the increase of voltage indicated when the bath is exhausted from alumina can throw no light on the respective electromotive forces required to decompose the various compounds.

To my mind there is only one phenomenon in the electrolytic process under discussion which clearly indicates that the reaction takes place, and that is the evolution of carbonic oxide at the anode. There is no doubt that in case oxygen was liberated by electrolysis, this oxygen would combine with the carbon of the electrode to produce carbonic acid, since it is well known that carbon in pure oxygen invariably burns to carbonic acid, and not to carbonic oxide. Therefore we cannot escape the conclusion that the carbonic oxide is generated by a chemical reaction, and this consists in a combined attack of carbon and fluorine liberated from the aluminum fluoride on the oxide, according to the equation Al_2 or $_3 + 3C + 6F$, equal to $Al_2F_6 + 3CO$. This reaction is very similar to that by which Deville manufactured aluminum chloride for his old chemical aluminum process, Al_2 or $_3 + 3C + 6Cl = Al_2Cl_6 + 3CO$.

One might feel inclined to explain the evolution of carbonic oxide, which undoubtedly takes place, as appears from the amount of carbon consumed for each pound of aluminum produced, from a subsequent reduction of the carbonic acid by the carbon, but this only occurs in case carbonic acid is led over a red-hot carbon. It is not the case in our bath, since only that part of the carbon cylinders is red hot which represents the electrolytically active zone, that is to say, that part of the carbon surface at which the anion is liberated. A reduction of carbonic acid to the oxide is therefore excluded. Another objection to the reduction of alumina by secondary action might be found in the fact that positive copper electrodes are said to be capable of substituting carbon. This is only true in as far as copper is capable, by its affinity for oxygen at higher temperatures, to substitute carbon as long as metallic copper is exposed to the dissolved alumina, but as soon as this no longer happens the current simply decomposes the original fluoride, which latter is no longer regenerated by alumina.

The fact that the fluorides waste only slightly is by no means a proof that they are not acted upon by the current. The fluorine being liberated at the anode in the most immediate vicinity of alumina and carbon, there is no chance for the fluorine to escape; it must act on the alumina. Examples of the secondary reaction in the electrolytic processes are frequent, and nowhere is there waste of the true electrolyte observed. Take, for instance, an anode of copper pyrites, place it into a slightly acidulated solution of copper sulphate, and pass the current; there will be a decomposition of copper at the cathode, and sulphur will drop from the anode, while the copper sulphate solution remains perfectly unchanged and constant.

It is, then, my opinion that the cycle of reactions by which aluminum is produced in the various electrolytic processes, in whatever form they may appear, is the

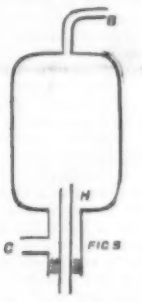
following: The current acts on the aluminum fluoride, aluminum is deposited at the cathode and fluorine at the anode. The free fluorine at once exerts its affinity for the aluminum in the alumina, and with the help of carbon forms aluminum fluoride, and at the same time carbonic oxide is formed. The aluminum fluoride in turn is decomposed. This interpretation is more or less distinctly anticipated by Deville and the various patentees and inventors who adopted his ideas for the manufacture of aluminum.

Deville, in order to make the action of fluorine on alumina in presence of carbon more efficient, intimately mixed the alumina with the carbon, and made the anode out of it, which he placed into fused cryolite. Lossier, in a patent granted by the German government in the year 1884, clearly expresses the idea that the fluoride is decomposed, and that the liberated fluorine together with carbon regenerates the fluoride bath by jointly acting on silicious alumina, as I have mentioned above. He is the first who fed in alumina, or rather silicious alumina as such, unmixed with carbon. I quote from his specifications: "Attraction of the aluminum silicates serving as aluminum ore is thus directly used for the feeding of the electric bath," and further, "this arrangement forms consequently an apparatus for continuous manufacture because the introduction of raw material and the gathering of the manufactured metal can take place without interruption."

Bell, in his English patent of the year 1861, has simply adopted the ideas of Deville. He regenerates his cryolite bath by feeding alumina into the same, by making it a part of the anode. In examining thus the principles and ideas by which aluminum hitherto has been produced on a commercial scale we cannot help concluding that all of it has been produced by methods worked and suggested by Deville. That Deville preferred to work his purely chemical processes is obviously due to the fact that at his time electricity could not be obtained cheaply, and only after the epoch-making application of electric heat and energy, made by Messrs. Cowles, to the manufacture of aluminum, which, in turn, as is on record in the history of dynamo-electric machinery, has given impulse to the manufacture of large dynamos, has the manufacture of aluminum attained its present great development, and the fact has been demonstrated that purely chemical processes are a matter of the past.—*Engineering and Mining Journal.*

THE LIGHT FROM BURNING SODIUM.

IN the course of some lectures delivered recently at the Royal Institution by Professor Dewar, a curious experiment by M. Cornu was repeated, bearing relation to the question whether the yellow light emitted by flames charged with common salt is due to metallic sodium or to the undecomposed molecules of chloride of sodium. Into a large glass globe a tube, H, Fig. 3,



conveying hydrogen to the flame at the mouth of the tube was inserted; the hydrogen was charged with solution of chloride of sodium by means of an ordinary spray jet; through C chlorine entered, and the products of combustion were carried off through B to potash apparatus, to prevent the fumes entering the theater. Under these circumstances, in an atmosphere of hydrogen burning in chlorine, it is impossible that metallic sodium can exist, and an ordinary hydrogen instead of the yellow sodium flame is seen. This shows that in ordinary flames charged with common salt the yellowness is due to free metallic sodium.

ASTRONOMICAL PHOTOGRAPHY.

TOWARD the close of the 1890-91 Royal Institution session now at an end, one of the Friday evening lectures at the Royal Institution was delivered by Dr. David Gill, H. M. Astronomer at the Cape of Good Hope, on "An Astronomer's Work in a Modern Observatory." In that part of his lecture which related to astronomical photography, he said that at the Cape observatory a guide telescope follows the one which is doing the work, and an observer watches through this guide telescope for forty minutes or an hour, to correct any small errors made by the moving mechanism, and to keep one of the stars in the field of view accurately on an intersection of the spider lines. The objective by which the photographic image is cast is a 6 in. rapid rectilinear Dallmeyer lens.

He said that their chairman that evening, Dr. William Huggins, was the chief pioneer of the photographic spectroscopy of the stars, and having led the way, had to leave some branches of the subject to others. One branch, that of the spectroscopic measurement of the motion of the stars in the line of sight, had been taken up by Dr. Vogel, of Potsdam, who had achieved great results, and the secret of his success was that he had an instrument constructed for doing but one class of work, and doing that work well. In getting the lines the photographic plate does more than the eye; when to the eye the lines are not there because of vibrations due to different causes, the photographic plate often registers them, because if they leave their place for a moment they come back again, and the action previously started on the plate goes on again. The line, G, in the violet is a convenient one to use in this work, because of the actinic intensity of the light at that part of the spectrum.

The principle on which the measurements are made is this: Suppose a locomotive rapidly approaching the observer to sound its whistle, more waves of sound will enter the ear in a given time than if it were traveling away from the spectator, and the listener can tell the change of sound by its "pitch." This analogy holds good in the case of light. When a star is approaching the spectator more waves of light enter the eye in a second, when the star is receding fewer waves of light enter the eye in a second. Let a spectroscope be interposed, these changes are indicated by a slight shifting of the position of the lines of the spectrum, and the amount of this shifting can be measured. By this means, as an example, it has been ascertained that Sirius is approaching us at the rate of 15½ miles a second. The motion of Alpha Aurigæ could not have been ascertained without the aid of photography. Beta Aurigæ has been discovered by Vogel to consist of two stars revolving around a common center, and if they are of the same mass they are each about twice the size of our sun. Their motions are so clearly indicated and regular, said the speaker, that by looking at their spectra through Vogel's telescope one can almost tell what o'clock it is.

Photographic observations of the Milky Way show that it is a separate creation from the rest of the universe, and probably a later one. There are portions of the belt of Orion which seem to be in a state of stellar evolution.

Dr. Gill here gave an outline of the nebular theory of Pierre Laplace, which assumes diffused gases in space to be condensing; that as contraction goes on the velocity of the revolving motion becomes greater, and may throw off rings which afterward become planets, while the central and still very hot mass acts as a sun to those planets. He finished by projecting upon the screen a most remarkable photograph of a nebula in Andromeda, recently taken by Mr. Roberts, in which a central luminous haze is surrounded by several nebulous rings, and Dr. Gill concluded with some remarks that photography dispassionately recorded the appearance of the objects subjected to its influence, without bias toward any particular theories of men.

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